MONTERIA

CENTURION

Centurion Offline Analyzer

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19. Centurion Offline Analyzer

19.1 Introduction and basics.

19.1.1 Introduction.

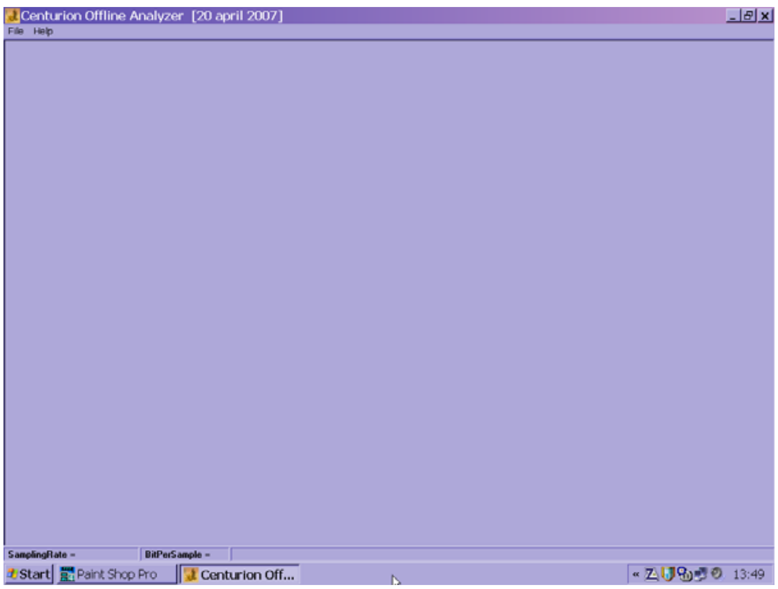
This facility permits the User to analyze an unknown signal which has been recorded in .wav format. This offline approach is so that analysis may continue long after the signal has gone off-air and permits the User to concentrate on a relatively good selection of the recording.

Usage of the analyzer is further discussed below under various headings:
FSK PSK MFSK OFDM QAM Multimode bursts.

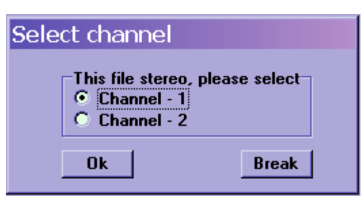
These six sections deal with basic analysis. However life is full of variants and the user should read. in conjunction Section 19.11 Analysis Considerations

19.1.2 Files - loading and restrictions

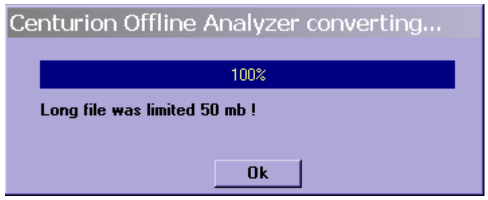
On opening the facility (Tools|Offline Analysis Tool) the basic screen appears.



Loading the required file is achieved by clicking FILE|OpenAudioFile and navigating to/selecting it using the Open dialogue. If the file is Stereo the user is presented with



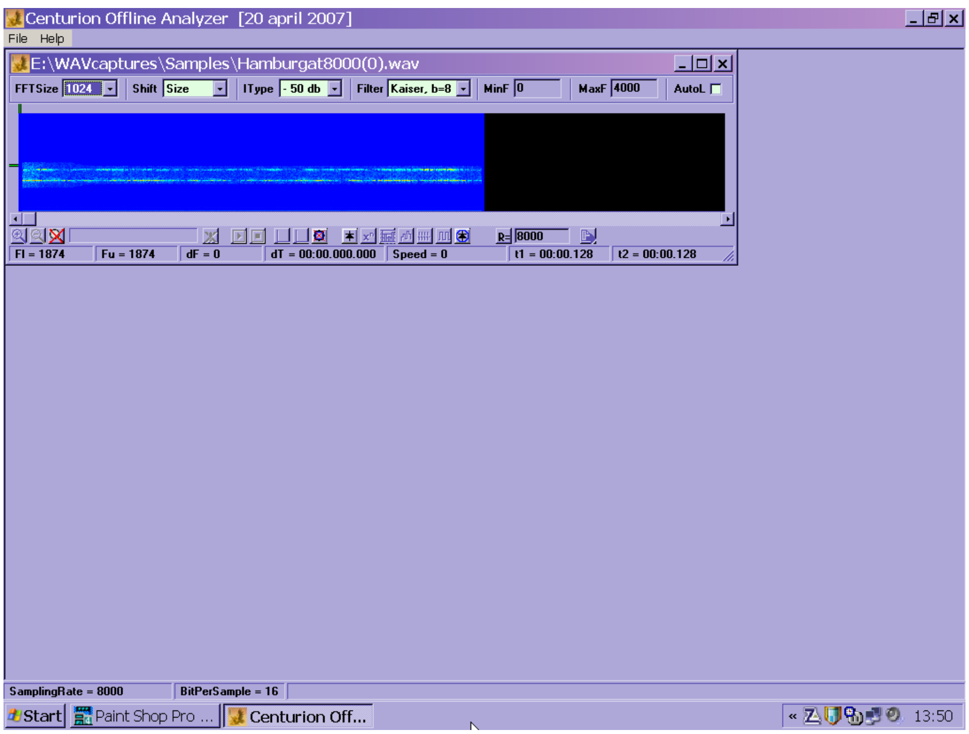
COA supports all formats, which have a WAV RIFF Microsoft PCM header with 8- and 16-bit sample rates. 8 bits not optimal... except with A/Mu-Law compression.



Maximum size sample is ~50 MB uncompressed data. If file is compressed, and is 20 MB or larger, a max. 48-50 MB of decompressed data will be loaded at once.

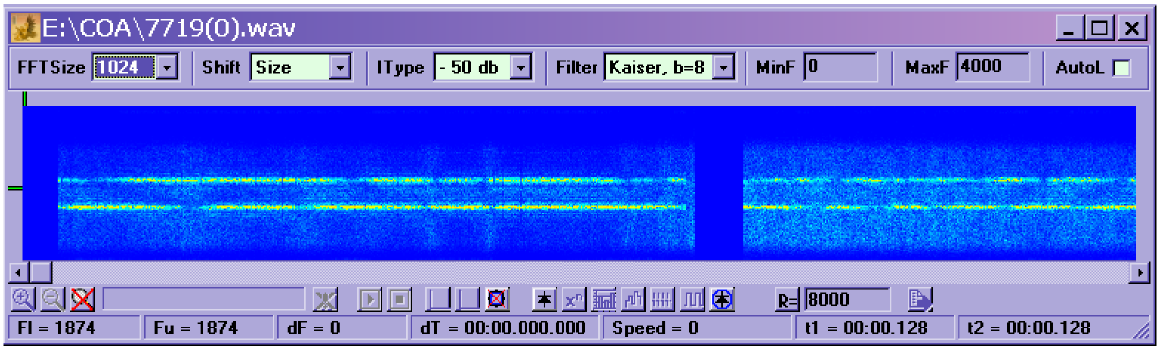
COA can load raw samples as data, without any specific headers... as 8 or 16 bits, integer files. Raw data can be interpreted as complex (even or odd).

Loading completed the screen changes to:



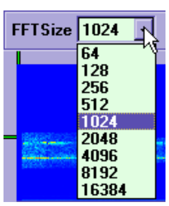
Note that the main window status line indicates the file sampling rate and Bits/Sample.

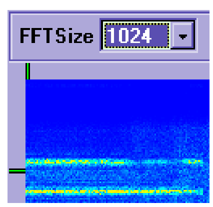
19.1.3 Basic window and manipulation.

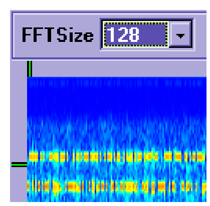


The Title Bar shows the full file path and name. Note that it also shows in brackets the window ID (in this case 0 = Parent). Since the facility opens a number of Child windows make a note of this as each is opened.

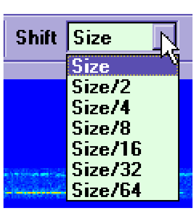
Four drop menus permit various aspects of the signal in the window to be adjusted.

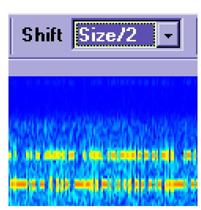


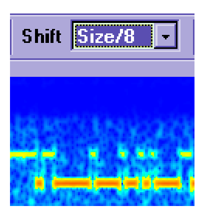




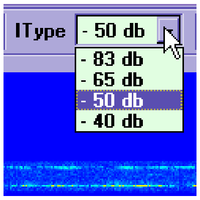
Adjusts the FFT size in use.

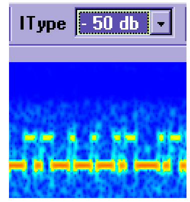


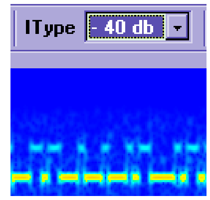




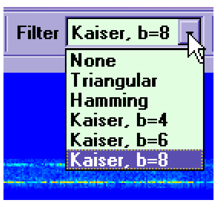
Performs a Zoom function along the horizontal (Time) axis. The position of the data displayed relative to the full recording is determined by the relative position of the horizontal slider under the window.

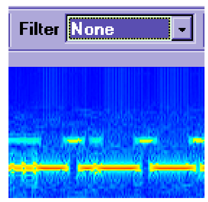


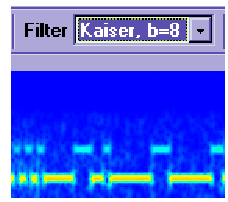




This adjusts the Intensity (amplitude) of the signal. Tones should be yellow with a little red. Intensive red indicates the signal is being overdriven (causes distortion) and should be avoided.

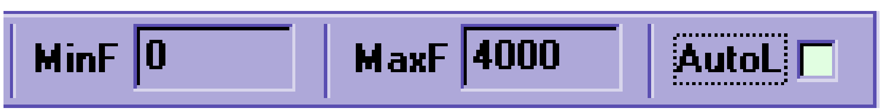


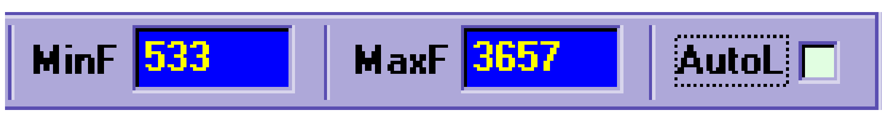




Sets the type of Filter shape (and degree) applied to the signal in the window.

Note that the four parameters above are pre cursor selection and applied to the whole file.

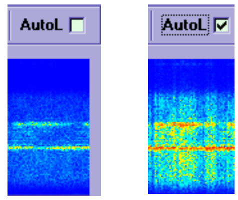




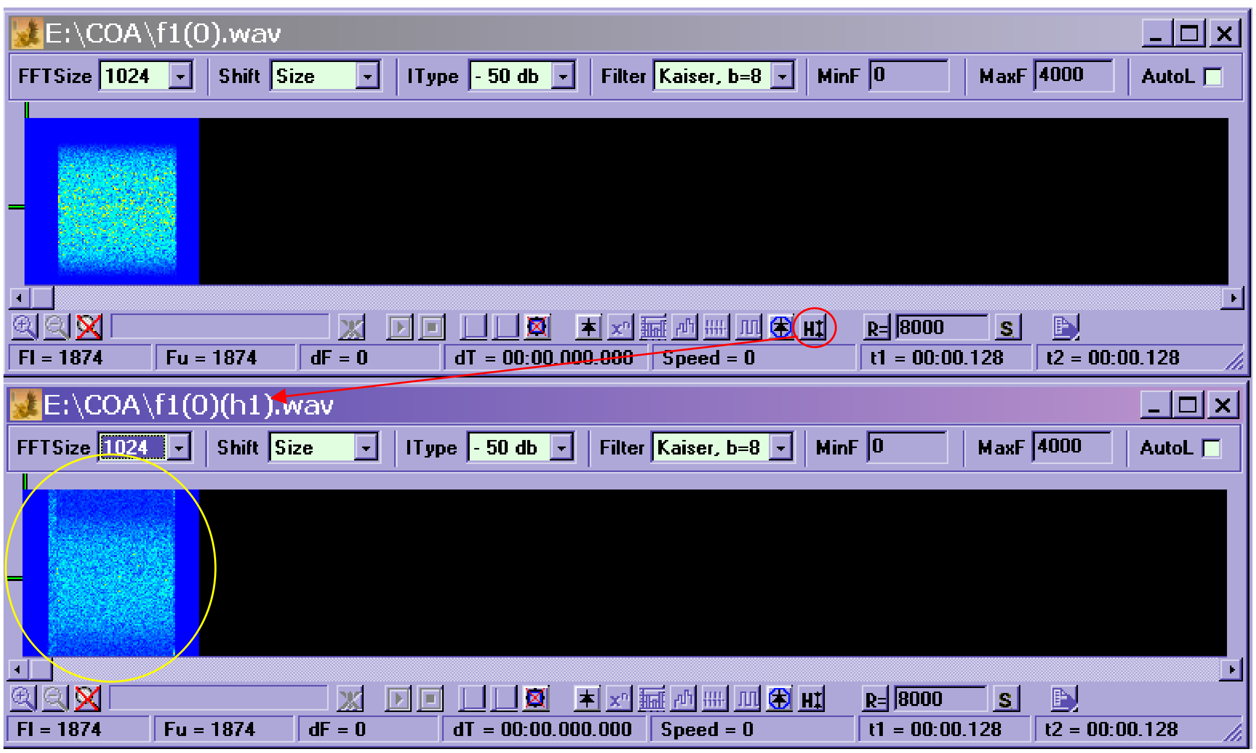
These values - MinF (lower) and MaxF (higher) - indicate the range of the visible spectrum in the work window. If there is a blue background then zoom is in use and there is a restricted area of view of the spectrum.

19.1.4 Level setting

AutoL (AutoLevel) provides on-click functionality by adding an averaged/optimized amplification thus giving a quick look at a signal's structure as a means of assisting in the decision of what steps to take next.



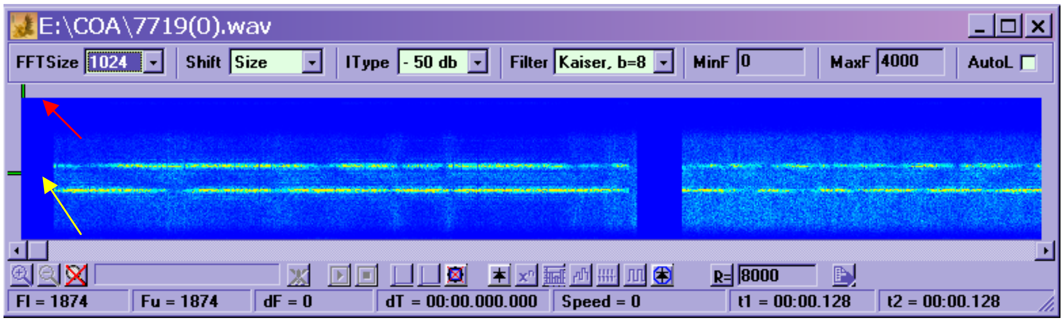
Alternatively on the Tool Bar one can click H to provide Hard ALC (Automatic Level Control) with output in a new **h** window.



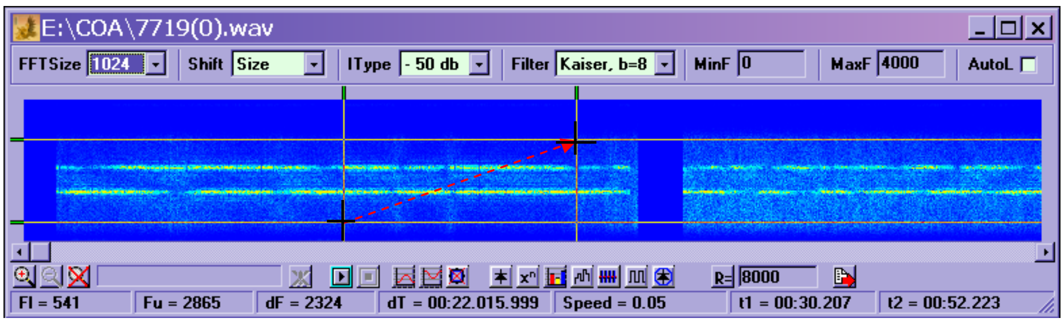
Compare the difference in the **h** window compared to it's source.

Read in conjunction with Section 19.11.2.2

19.1.5 Cursors.

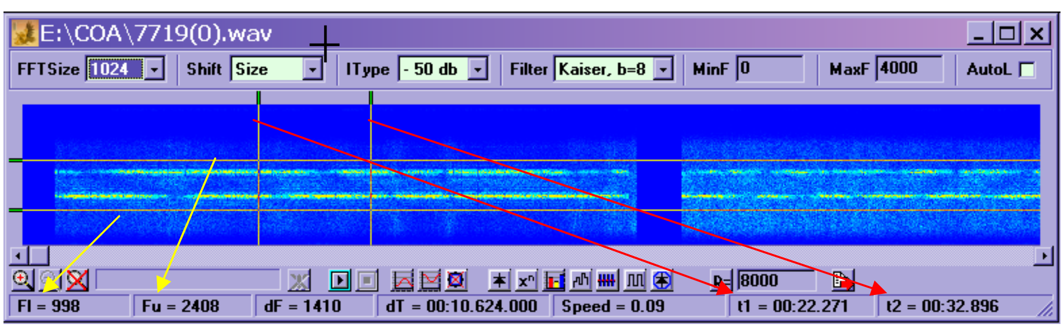


The two arrows show the cursors' initial positions. Clicking and dragging these points (at the green handles) will produce a second cursor with another one extended from the initial point.



Alternatively one may click and drag across a selection area to set the cursors. The mouse cursor changes to a cross during this operation.

Each set of cursors may be used as a pair (maintaining dF or dT) by clicking between the handles and dragging as appropriate.



These can now be individually moved to measure (see value in Status Bar) frequency and time.

Fl	Frequency (Lower) in Hz
Fu	Frequency (Upper) in Hz
dF	Frequency Difference (Fu-Fl) in Hz
t1	Time (Lower) in Min:Sec.mS
t2	Time (Upper) in Min:Sec.mS
dT	Time Difference (t2-t1) in Min:Sec.mS

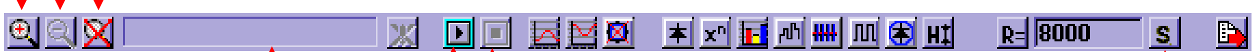
19.1.6 Tool Bar:

19.1.6.1 Frequency (vertical axis) zooming

Freq Zoom + (Not enabled until frequency cursors appear/defined)

Freq Zoom - (Not enabled until signal zoomed).

Reset Freq Zoom (to datum)

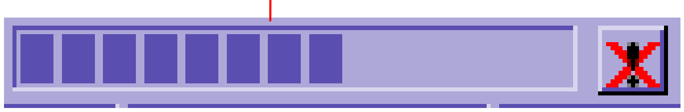


Shift/Shift Bandwidth.
Refer Section 19.11.6

19.1.6.2 Audio playback

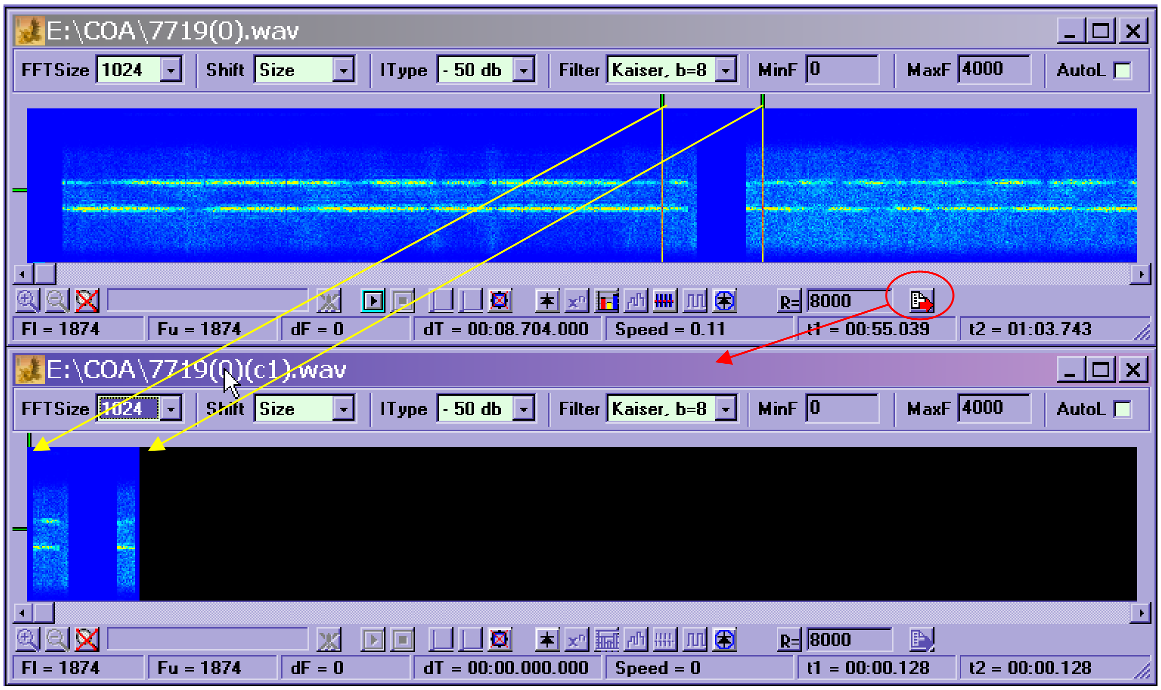
StopPlay (Not enabled until play initiated.)
StartPlay. (Plays file section defined between cursors t1 and t2 to LINE OUT.) (Not enabled until time cursors appear/defined)

19.1.6.3 Progress bar



When some processes are called these may require extended time. The Progress Bar indicates ongoing activity. The Break button to the right provides a means of terminating the process at any time.

19.1.6.4 Create Copy



It is useful to work on a restricted section of the original file which may provide a better quality of signal. To this end a copy is created.

In the Parent window (0) the section of the file to be copied is delimited by the time cursors. When the Create Copy button (also labeled New Window) (encircled in red) is clicked that section is copied to a new window which appears and takes focus.

Note also the new window IDs as c1 and the (0) indicates that it has window (0) as a parent.

Depending on the FFTsize/Shift values in the original window only a section of the file may be seen. When a small section is copied it may only partially file the new window as seen in this example. One may continue of course to enlarge this in the new window (c1) by manipulation of it's FFTSize/Shift parameter controls.

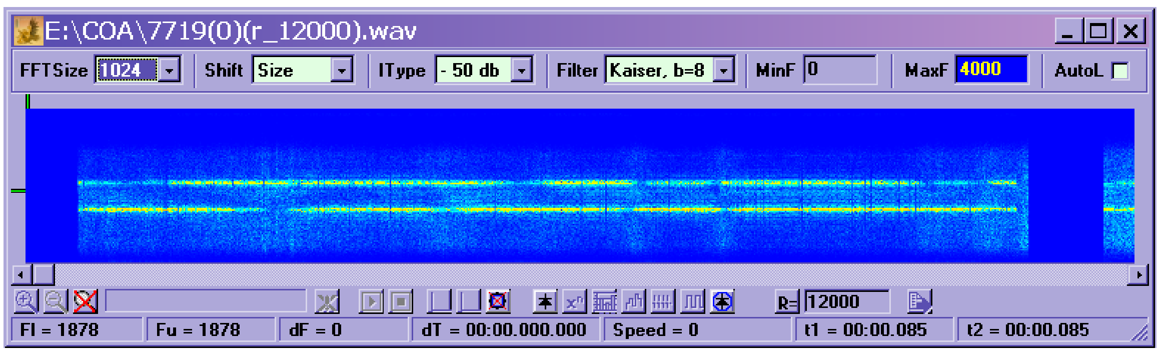
In turn this window in focus may become the parent of further Child windows.

19.1.6.5 Resampling.

This function is useful in the analysis of signals in .wav format. While the original file may be sampled at 8000 or 16000 samples/sec it is an easy matter to resample this to another value.

In the window of the parent file type in the required sample rate. The range is 4000 to >10000.

Click the [R=] button. At the end of processing (the whole parent file and not a selection of it) a new window will appear and be in focus.



Note that it's ID is **r** followed by the sample rate value.

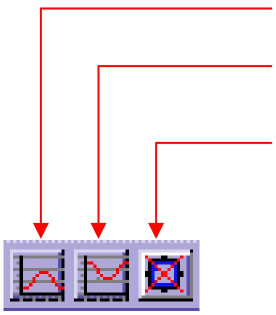
It will also be noted that the sample rate in the status line of the COA main window is also 12000. In fact it takes the sample rate for the window in focus.

In turn this window in focus may become the parent of further Child windows.

19.1.6.6 Filtering

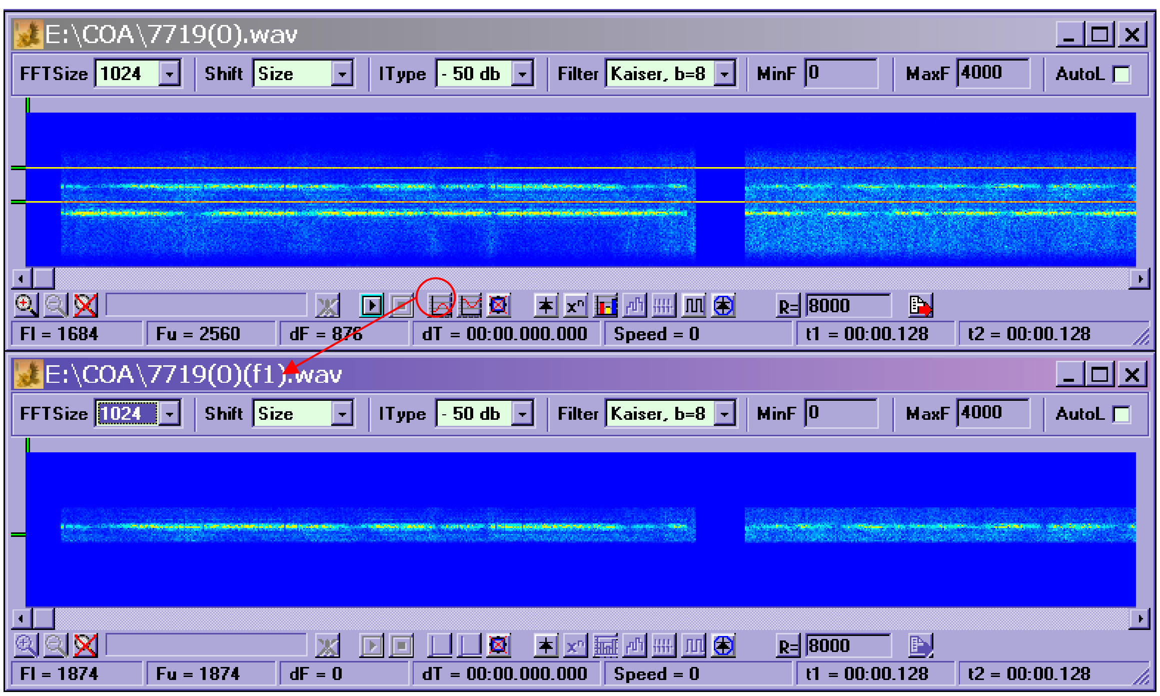
This group of buttons provides spectrum filtering.

Filtering (Select) New Window	[Band Pass]
Filtering (Reject) New Window	[Band Stop]
Filtering (Shape Reject) New Window.	[Returns focus to unfiltered parent]



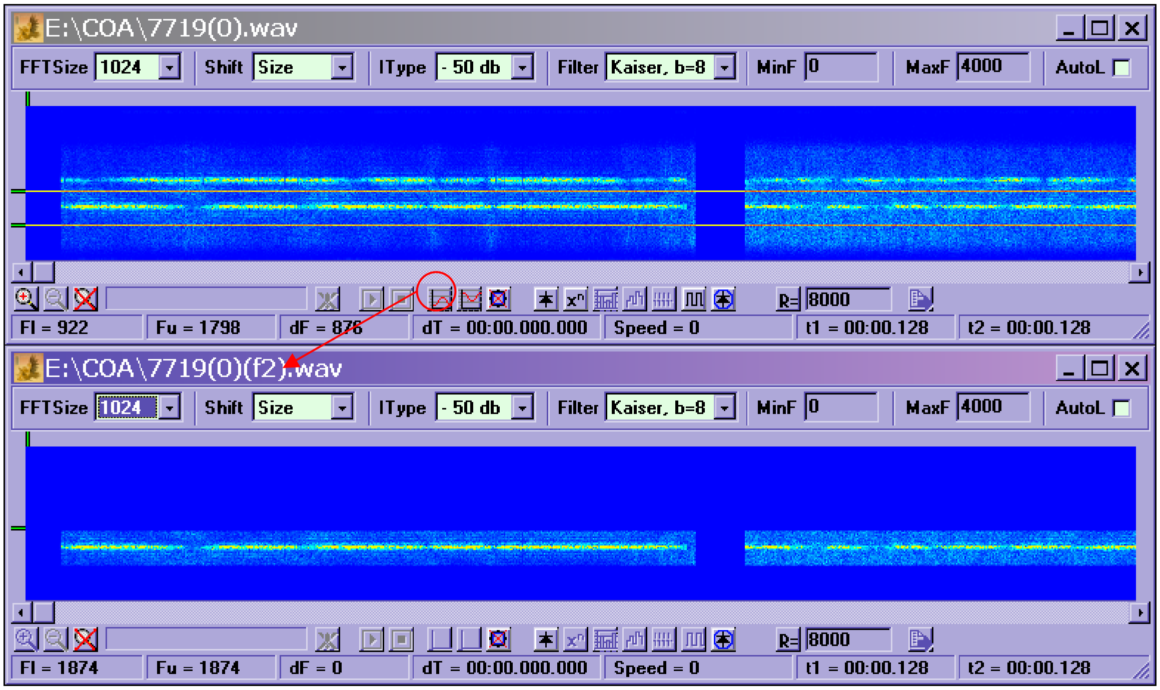
In the Parent window the section of the spectrum one wishes to filter must be encompassed or delineated by the frequency cursors. A child window is then created as seen in the examples below with focus switching to the created child window. Note that these windows have the ID **f** together with the next available serial number in that series.

Example 1 - Band passing (selecting) the upper tone:

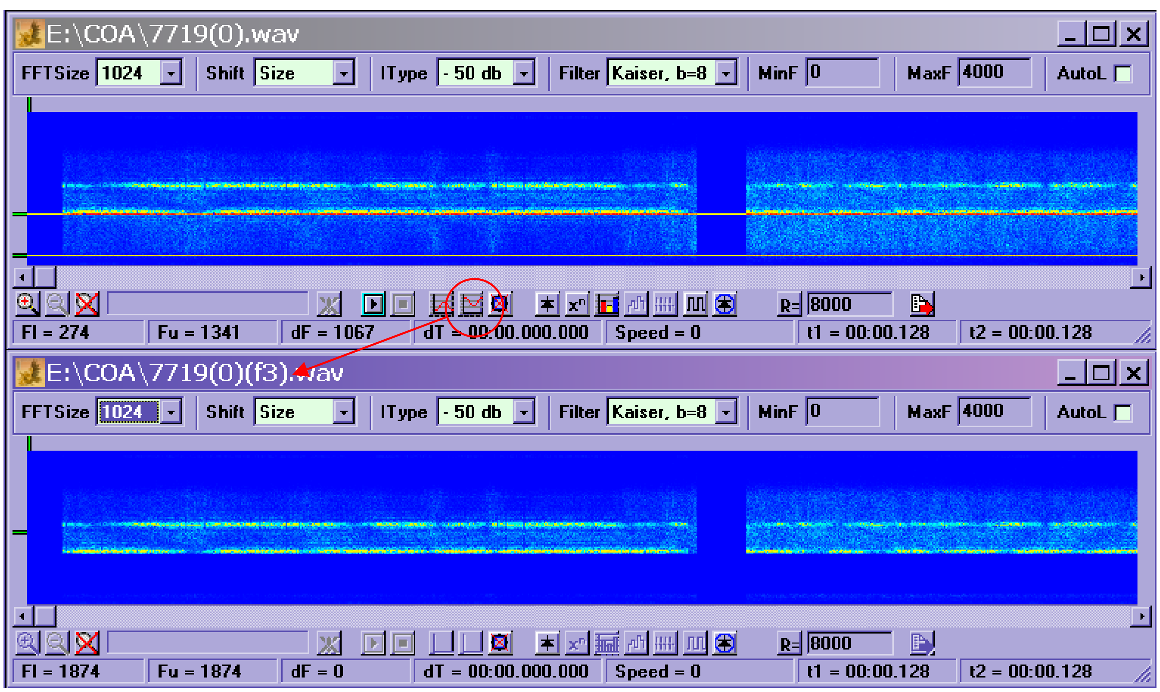


As before the child may become the parent for further stages.

Example 2 - Band passing (selecting) the lower tone:

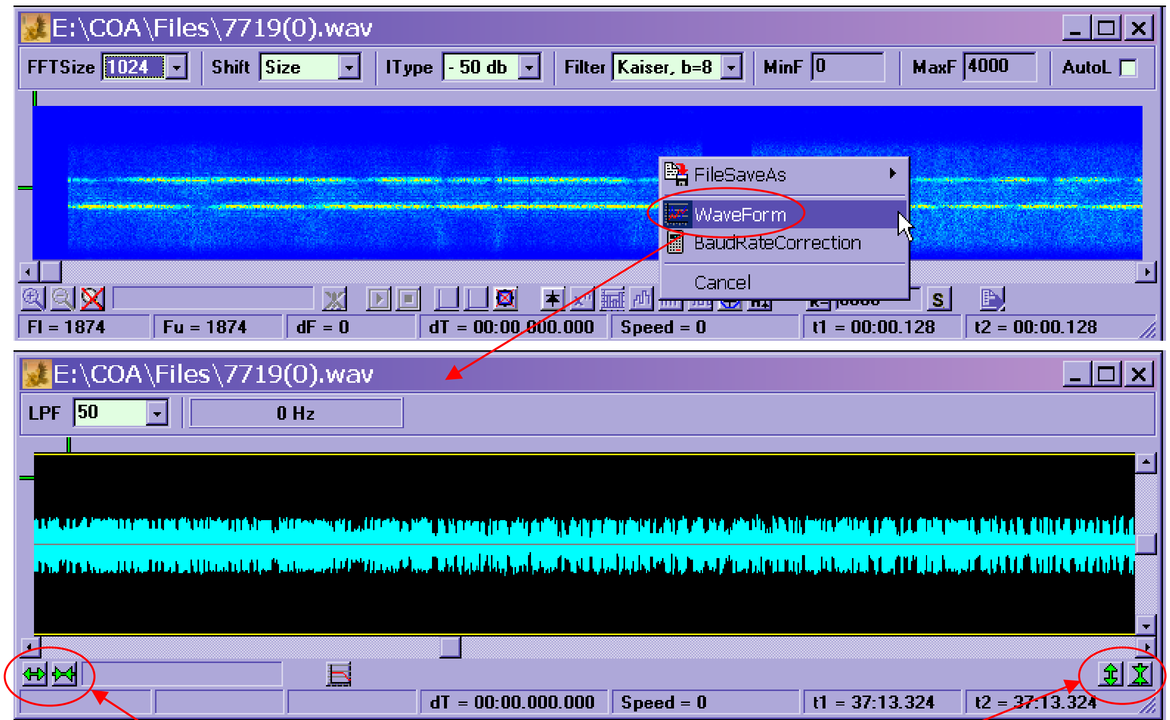


Example 3 - Band Stopping (Rejecting) the noise below the lower tone:

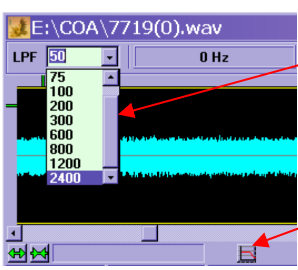


19.1.6.7 Viewing waveform

Right click the parent window to obtain a sub menu. Click Waveform to create a waveform window.



Zoom controls are available: Horizontal and vertical.



Low pass filtering may be applied by selecting the frequency from the drop menu then clicking the LPF Filtering button.

This should be set to the value at, or immediately above, the known or expected baudrate.

19.1.6.8 Preparing for analysis

The preceding tools permit the user to prepare the single for analysis with a view to setting levels, reducing noise and selecting best (or particular) sections for analysis. To summarize:

Presentation - FFTsize, Shift

Signal level - IType

Spectrum - Filter (basic)

Cursors - Time for length of file to analyze

Frequency for width of spectrum, with/without bandpass/band stop considerations

Resample - if necessary a change in sampling at the beginning, and repeat.

Typical preparation procedure:

Open the file.

Using horizontal cursors adjust to measure (approx) signal bandwidth.

Open these cursors to provide sufficient bandwidth as one would provide for the same signal through a receiver.

However if the signal spectrum requires further processing adjust the horizontal cursors in conjunction with the Select Filter to isolate wanted tones, or the Reject Filter to notch interference.

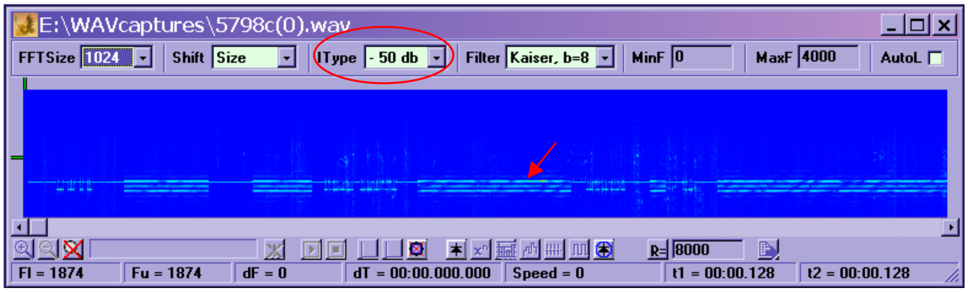
Both functions can be used to improve a signal by using the same method (and other Filter).

The signal should now be ready for analysis. It is prudent to create a copy.

Examine the signal for a good section (or specific) for analysis and mark limits with the vertical time cursors.

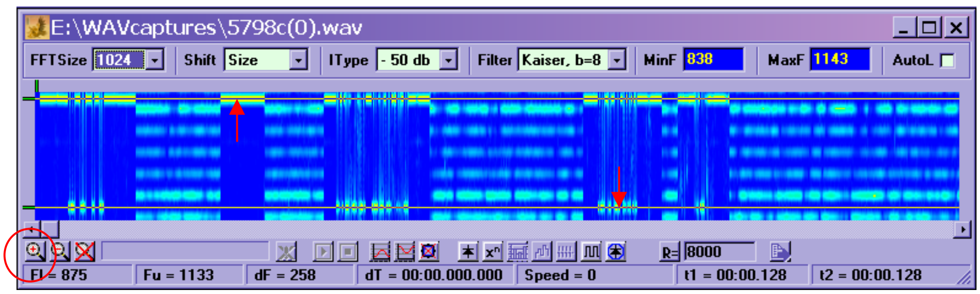
Create a copy (for subsequent working).

19.1.6.9 Typical preparation sample.



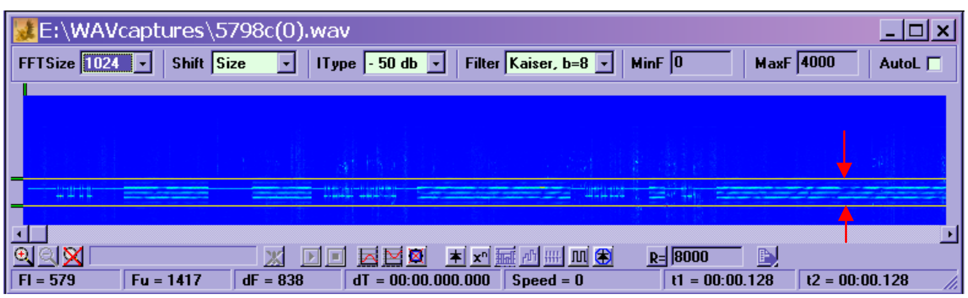
Load the file.

Confirm level at minimum red. If required adjust IType.

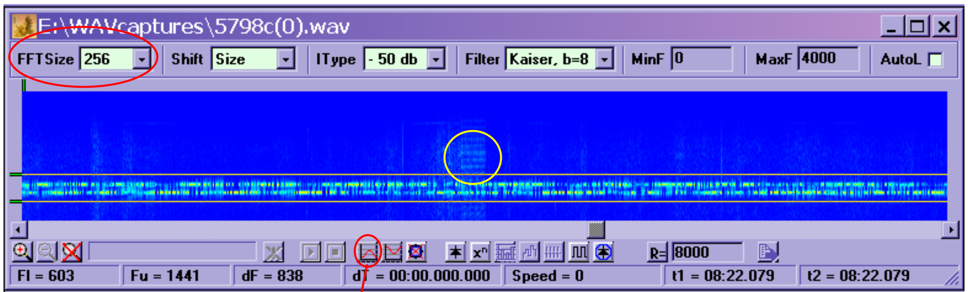


Call horizontal cursors, zoom in and set cursors through the two tones.

Initial measurement indicates signal shift (dF) of 258Hz

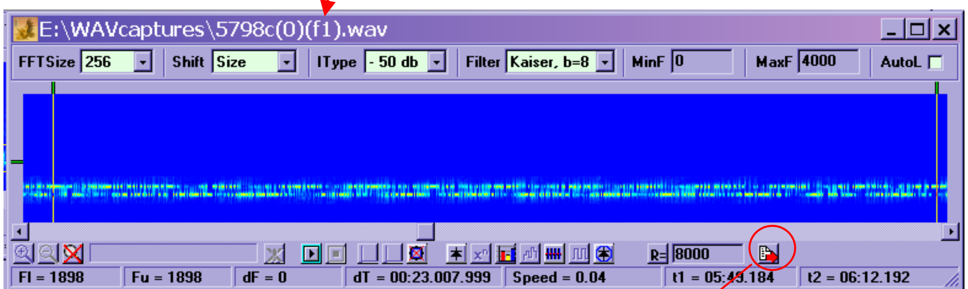


Adjust cursors to be outside the shift limits.



Adjust if necessary FFTsize to sharpen display. Use horizontal slide to position window relative to whole file where data for analysis resides.

Note the area of noise. This can be removed by bandpass filtering. Confirm positioning of the horizontal cursors to designate the filter edges. Click the Filtering (Select) button.

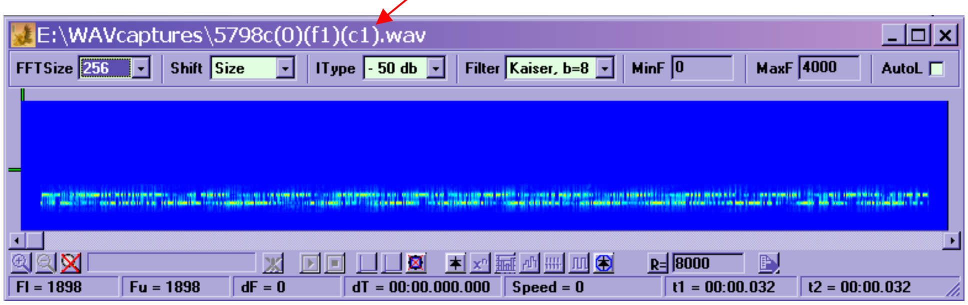


The noise has been removed.

Note the new window ID'd **f**

Adjust the horizontal slider to position wanted area of data in the window. Position the vertical time cursors to encompass this area. Note the parameter dT = 23 seconds. This should be more than sufficient for analysis.

Click the Create Copy button.



Note the new window ID'd **c**

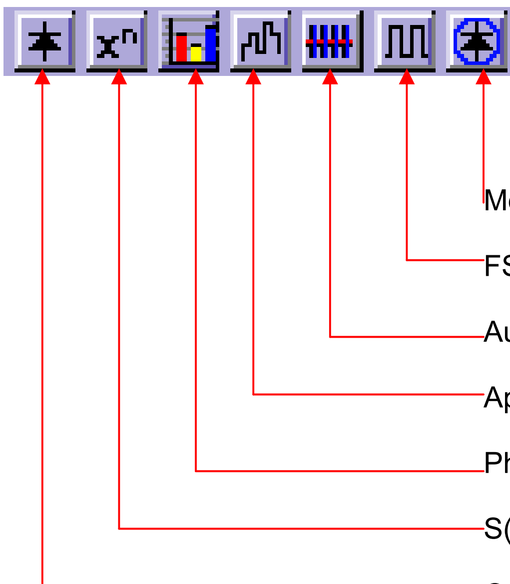
This is the signal prepared for analysis and window **c1** can be considered the parent for further analysis. Note also the linkage from the original parent 0 through f1 to this window.

19.1.6.10 Analysis Tools Group

This group are used in the actual analysis of signals and only summarized here. They will be discussed later as the need arises.

When they become active depends on whether certain cursors are enabled or not. The requirements are shown in the [..] brackets using the letters:

N Neither F Frequency T Time B Both.



Modify Quadrature Amplitude Detector	[NFTB]	{ um }
FSK Dem	[..F...B]	{ _fsk }
Auto Correlation Function	[......TB]	{ _acf }
Approximate One Freq	[.......B]	{ _aof }
Phase Viewer	[.....TB]	
S(t)=S(t)^n	[..F...B]	{ q }
Quadrature Amplitude Detector	[NFTB]	{ u }

Results are presented in a display window similar to those appearing earlier but each has it's own ID series, the letters used being shown above in the {..} brackets.

The Phase Viewer mentioned is expanded on in the next section.

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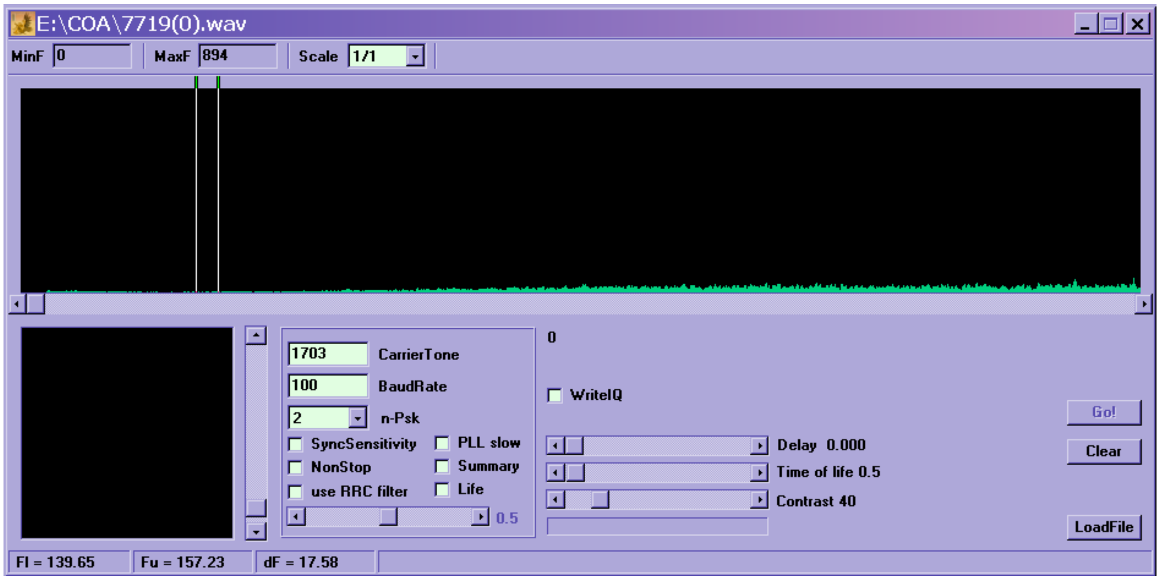
19.1.6.11 Phase Viewer.



When the Phase Viewer (also called the High Resolution module) is called this frame appears.

In general the upper window is used for measuring FSK signals, and the lower for producing phase constellations.

19.1.6.12 Ending analysis task.

The analysis task is complete the user is likely to have a number of windows open on screen. Rather than close down each individual window it is better to close everything together by clicking the Windows|CloseAll facility in the Menu Bar

19.1.7 Miscellaneous Functions

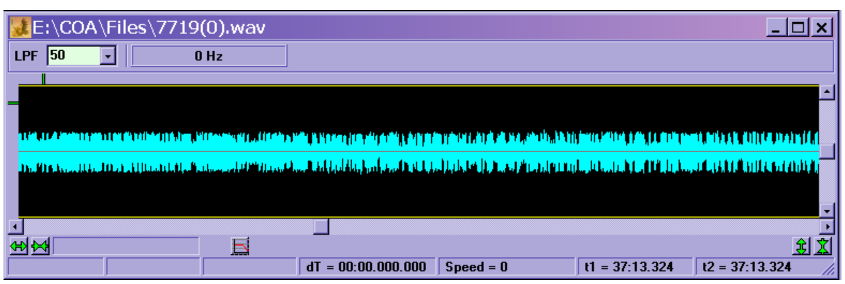
Not part of the Tool Bar but accessed by right clicking the window in focus to produce a small dialogue box:

19.1.7.1 FileSaveAs.

Clicking WaveFile will provide the Save As dialogue in order to save the current signal (having been modified by filtering/copying/etc) into a discrete user .wav file for later use.

19.1.7.2 Waveform.

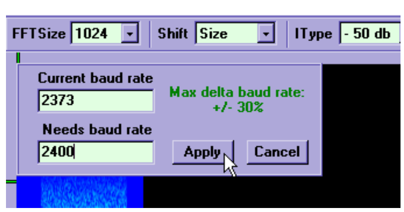
Clicking this option calls a new window.



Refer Section 19.1.6.7 (Viewing Waveform) for basic manipulation.

19.1.7.3 Baudrate Correction.

Clicking this option places a small entry option in the top left of the current window.



Refer Section 19.11.6 (Baudrate Correction Considerations) for it's use.

19.2 Basic route map

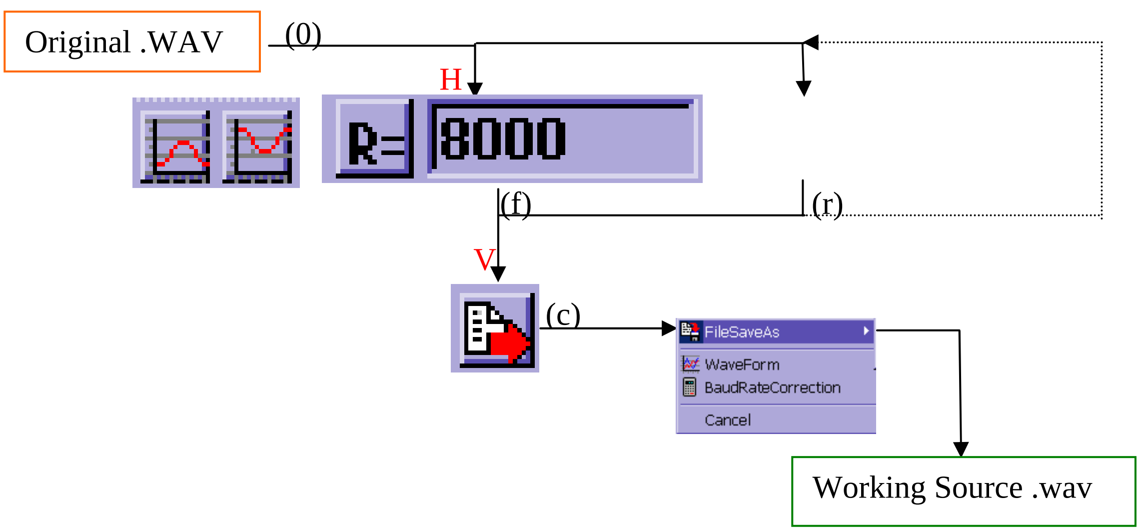
19.2.1 Foreword.

This is a route map or overview to assist assessing various parameters rather than a detailed description as discussed in the following sub-sections.. It is intended as an aide-memoire, or as a quick guide for beginners.

H and/or V — indicate the minimum setting (which needs be applied) to the Horiz/Vert cursors before clicking the following button.

(...) — indicate the resultant waveform.

19.2.2 Preparation.



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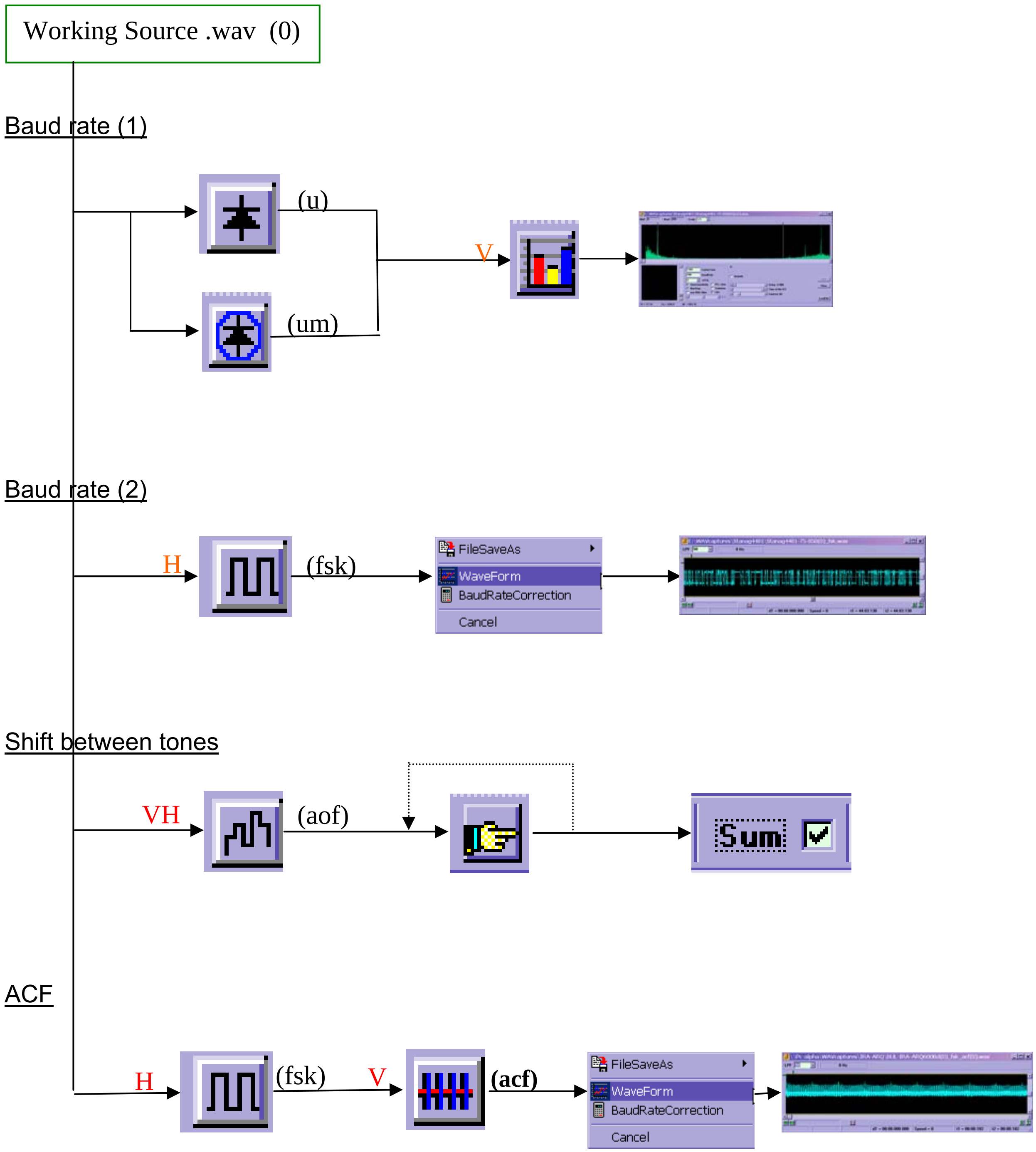
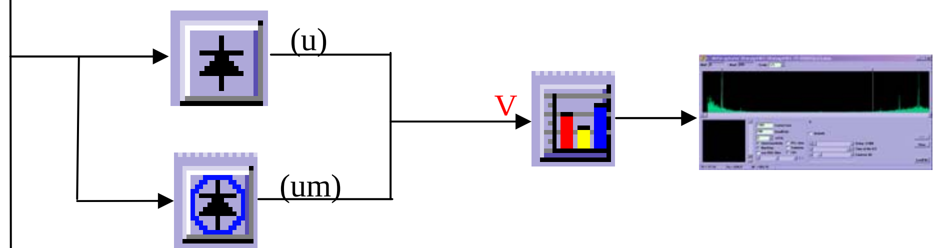
19.2.3 FSK

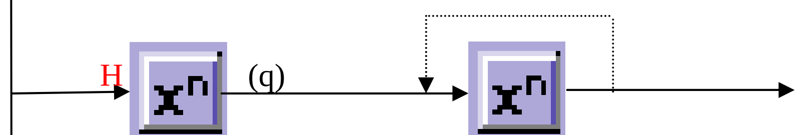


19.2.4 PSK

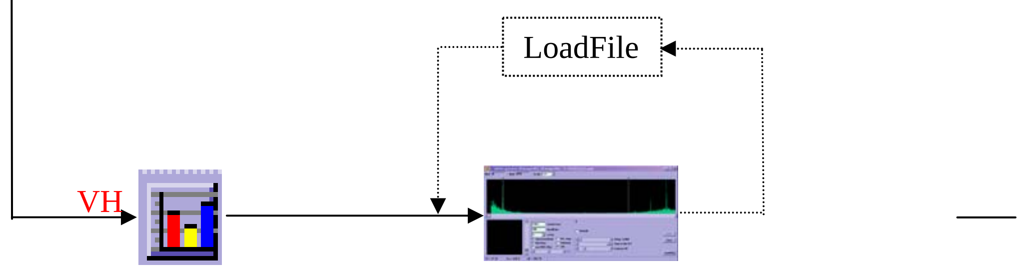
Determining Symbol Rate.



Determining n-ary, and subcarrier frequency.



Displaying phase constellation.



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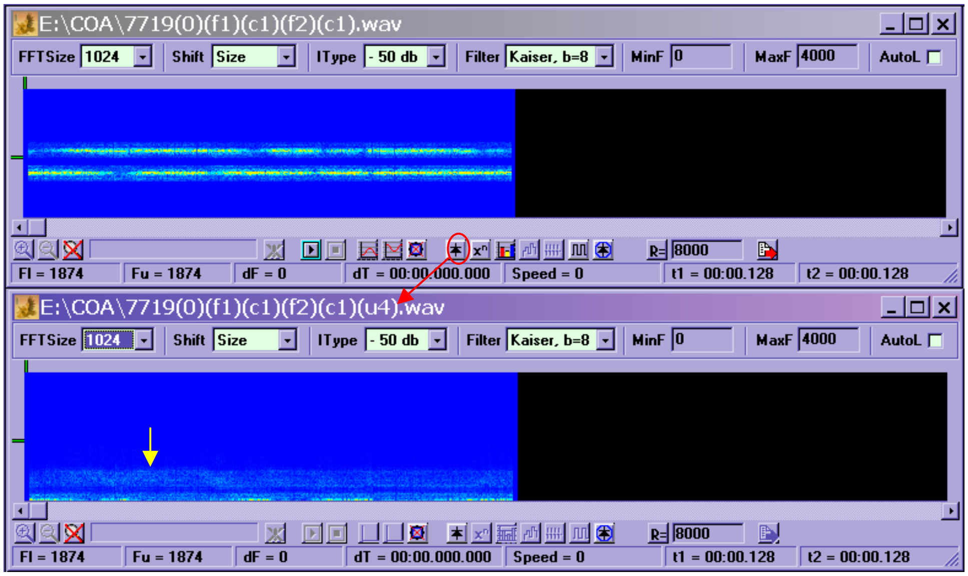
19.3 Analyzing FSK

Load and prepare the signal for analysis.

From this procedure initial data revealed is an FSK signal with tones of 1403/2088Hz and a signal shift of 685Hz. Centre frequency is 1746Hz. Spectrum bandwidth for analysis is opened to 1066Hz.

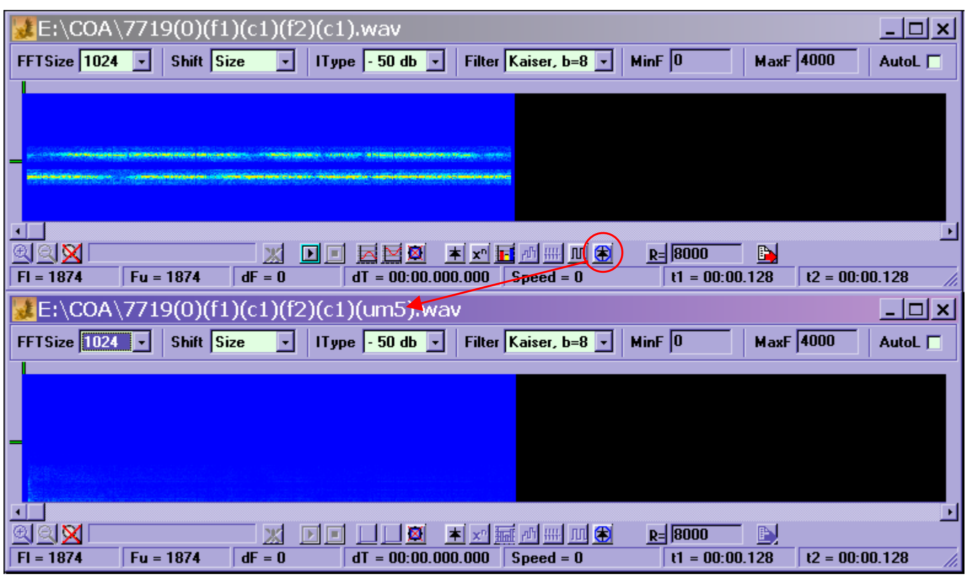
19.3.1 Baud rate.



Prepare signal.

Clicking this button produces a new window with **u** ID and calculating the baud rate by classic methods.

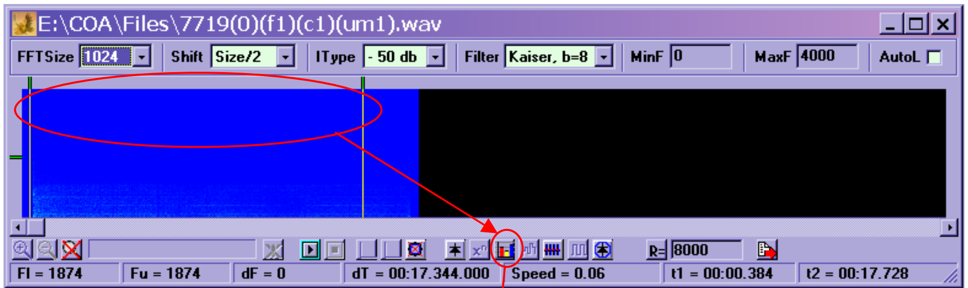
The weak screen shows some signal noise in it's result.



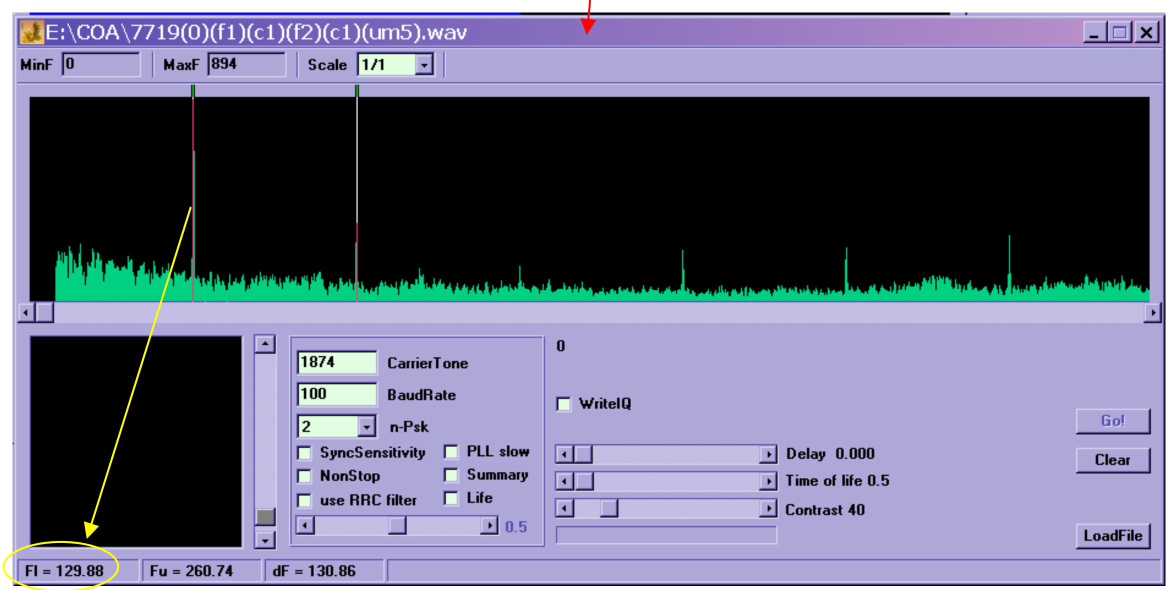
Alternatively and by returning to the same **c1** parent we can carry out a baudrate calculation using the modify AM method.

In this window ID'd **um** there is much less noise if any.

As above the **u/um** Results Windows show a nil/very weak display. Although this does not inhibit the procedures following, one should refer to Section 19.3.1.1.



Continuing with this window the time cursors are enabled to encompass the majority of the window. This causes the High Definition module button to become active. When clicked that module appears and presents the baudrate data calculated and retained in the **um** window.



In the upper window a number of spikes will be seen. Align the vertical Fl cursor with the LONGEST of these, and read the actual baudrate from the status line box. Use the Fu cursor to measure the smaller spikes. These will be found to be harmonics of the baudrate.

From this the unit bit period is 1000/129.88 = 7.7 mS.

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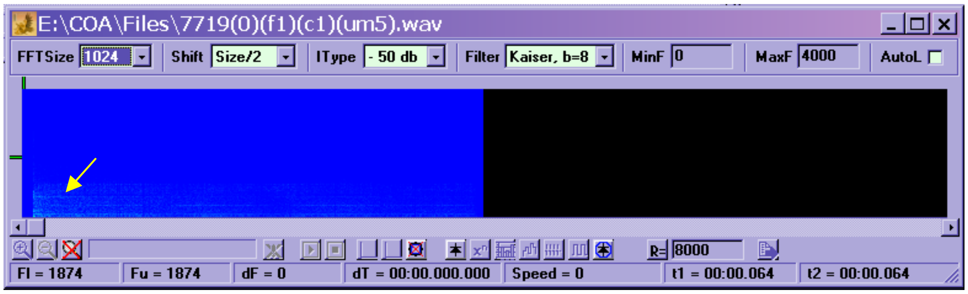
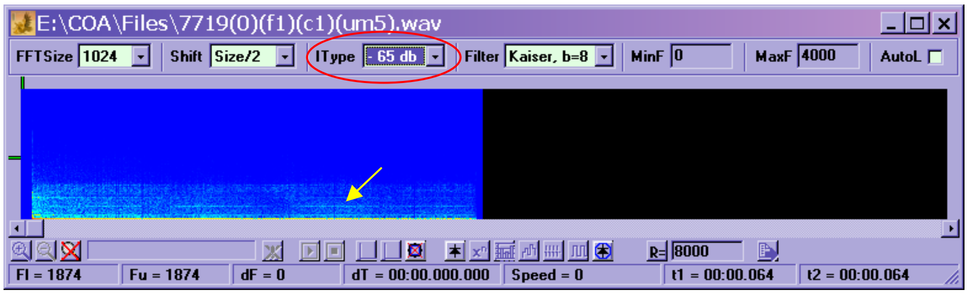
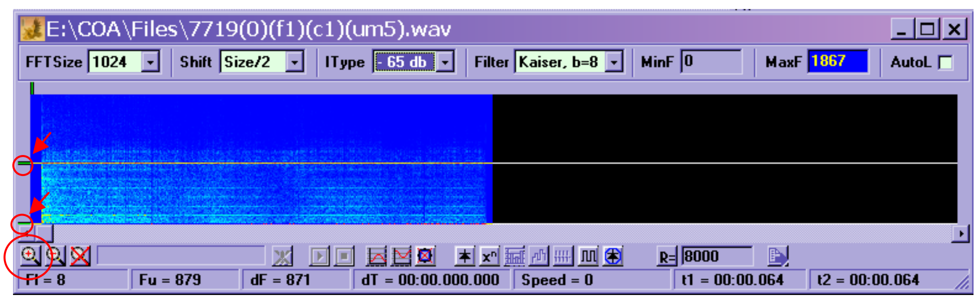
19.3.1.1 Improving u/um Results Window display



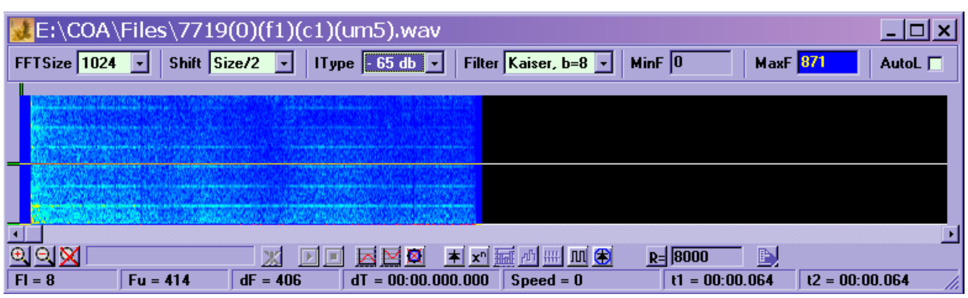
Datum window may have nil or very weak traces.



Intensity may be increased by adjusting IType. This should reveal faint horizontal lines representing baud rate and harmonics.



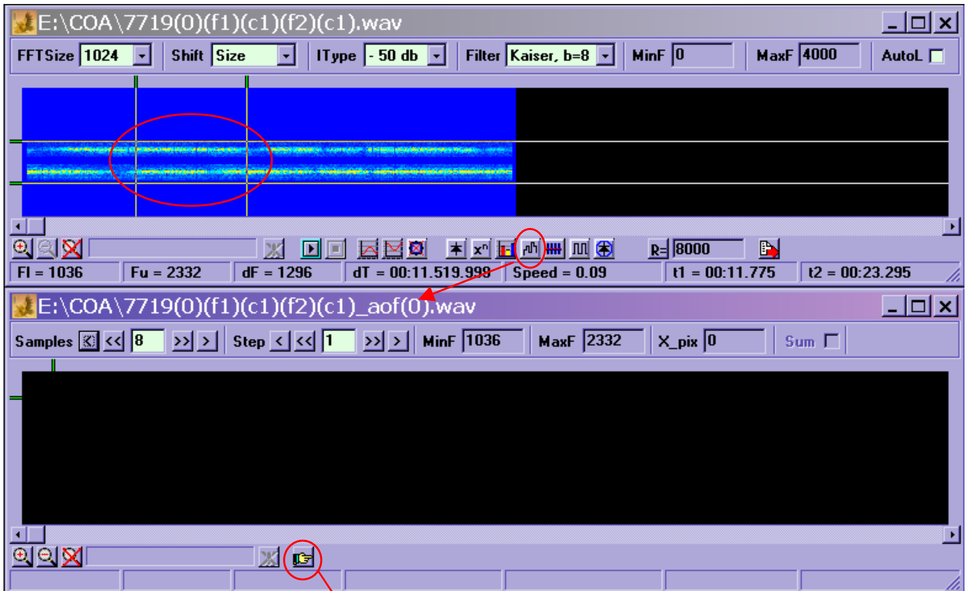
If still poor set the horizontal markers as shown. (note FI at minimum value.) This enables the vertical Zoom+. Click once.



This results in baudrate line and its harmonics being clearer. If not, click Zoom+ once more.

19.3.2 Measure shift between tones.

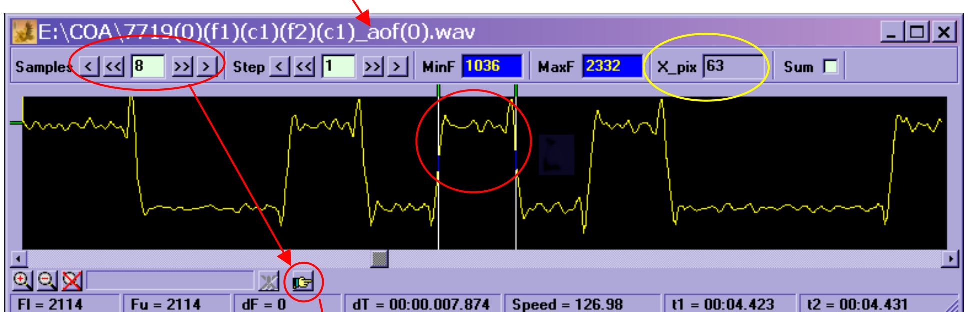
If child windows are still open from the previous stages close these, returning to the prepared signal in the parent window.



Select an area of signal, and then click the AOF button.

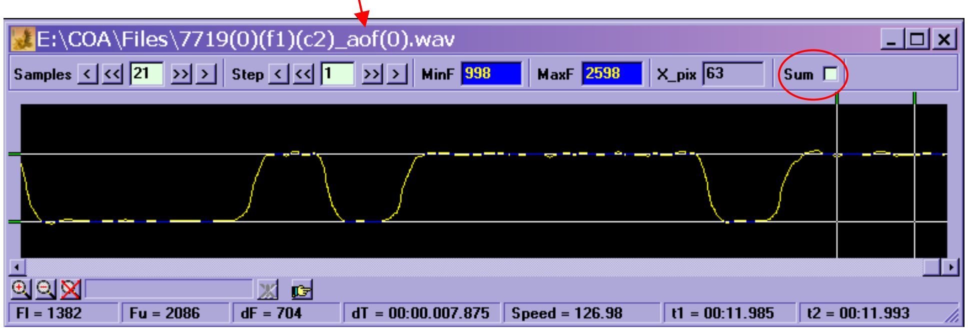
A blank window ID'd **_aof** appears.

Click the Make Image button and allow processing to complete.



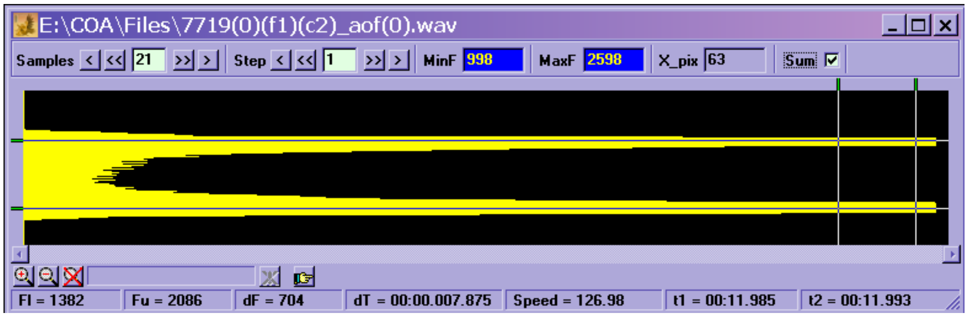
Using the horizontal slider find a section with alternating unit elements. Set the vertical time cursors to the leading and trailing edges of one such element. Note the X_pix value.

Divide the X_pix value by 3 (63/3=21) and set the Samples parameter in this window to the result. Click the Make Image button to update the trace.



On completion align the horizontal cursors with the tops/bottoms of the signal and obtain the accurate tone values together with the signal shift from the status line.

An alternative display can be produced by checking the Sum box.



A spike is built for each tone in the signal (in this case 2) which can be measured by the horizontal cursors.

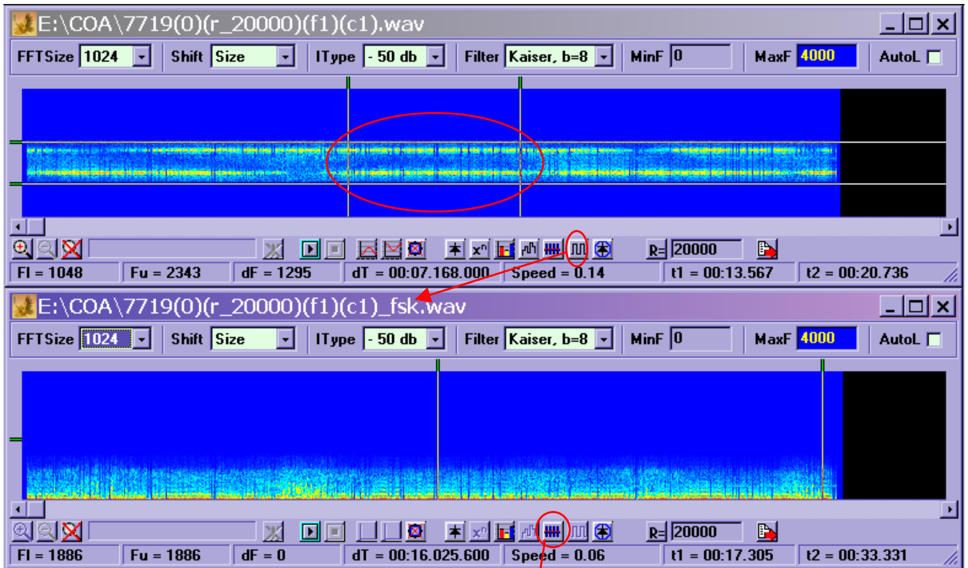
Returning to the Make Image function in the **-aof** window on the previous page note that

a. increasing the Step value results in more data elements on the screen, and

b. increasing the the Samples results in less ripple on the data.

19.3.3 Determine Autocorrelation Function.

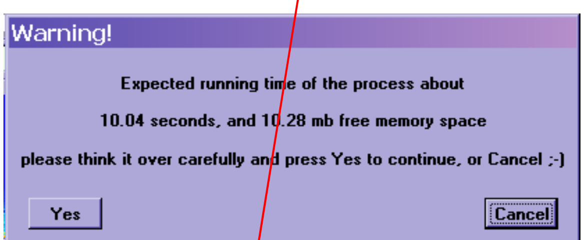
Prepare the signal. This example based on a resample to 20000.

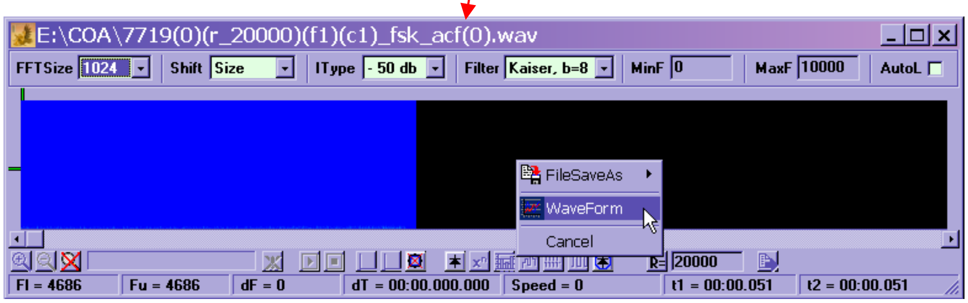


Select an area of signal, and then click the FSK Dem button.

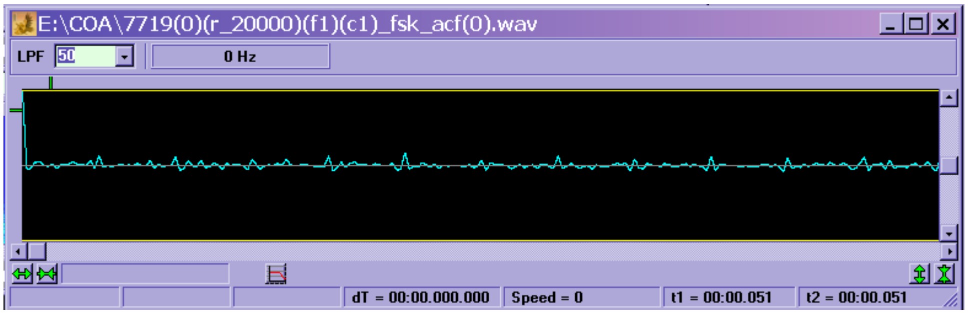
The window appears ID'd as **_fsk**.

Set time markers and click the Auto Correlation Function button. Depending on the processing required the following warning may/may not appear.

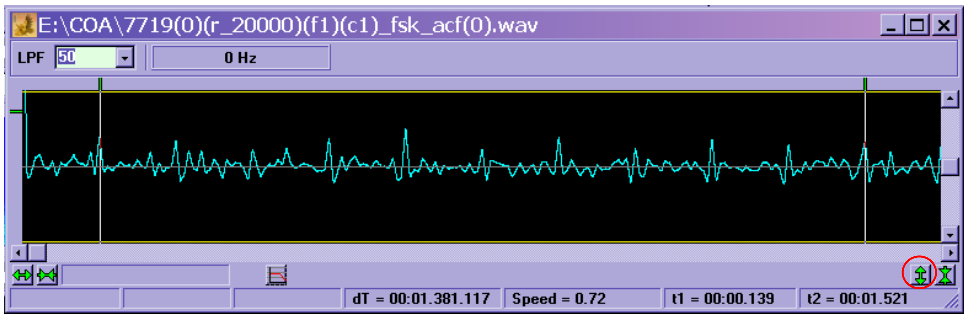




With the ACF data calculated in order to display this right-click the window area then click Waveform in the submenu.



Small ACF spikes may now be observed in the waveform viewer.



However if too small they may be made more pronounced by vertically zooming.

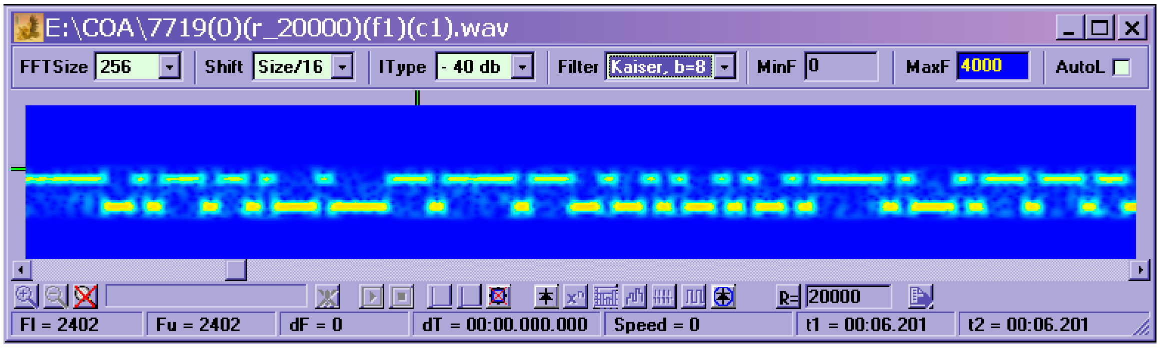
Set the time markers to obtain the ACF period between adjacent spikes from the dT value in the status line. However, it is better to measure over a number of spikes and use the average. In this sample dT is 1.381 seconds over 11 spikes (11-1 periods).

The ACF period is therefore 1381/10 mS = 138.1 mS.

ACF bits = ACF period/unit bit period (rounded to nearest integer).

e.g. 138.1mS / 7.7 mS = 17.93 = 18

19.3.4 FSK Example Results



Summarizing:

A classic 2-level FSK signal.

Upper limit of spectrum:	~2332Hz
Lower limit of spectrum:	~1036Hz
Signal bandwidth of spectrum:	~1296Hz
Upper tone:	2086Hz
Lower tone:	1382Hz
Center frequency:	1734Hz
Signal shift:	704Hz
Baud rate:	129.88bd
Unit element period:	7.7mS
ACF period:	138.1mS
ACF bits:	18

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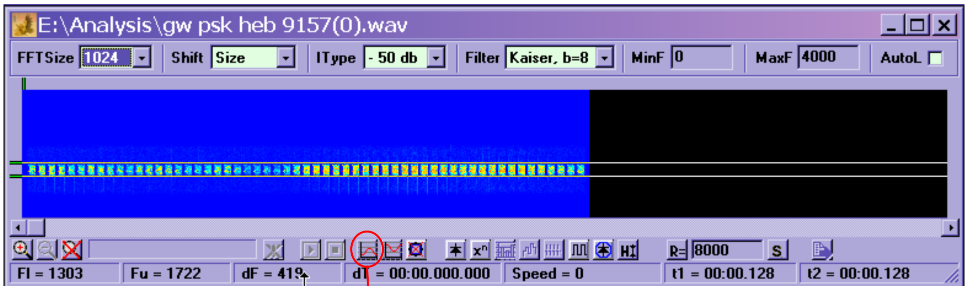
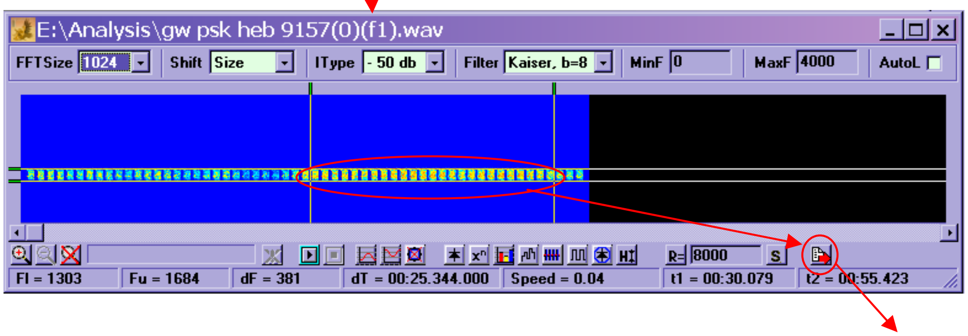
19.4 Analysing PSK (1)

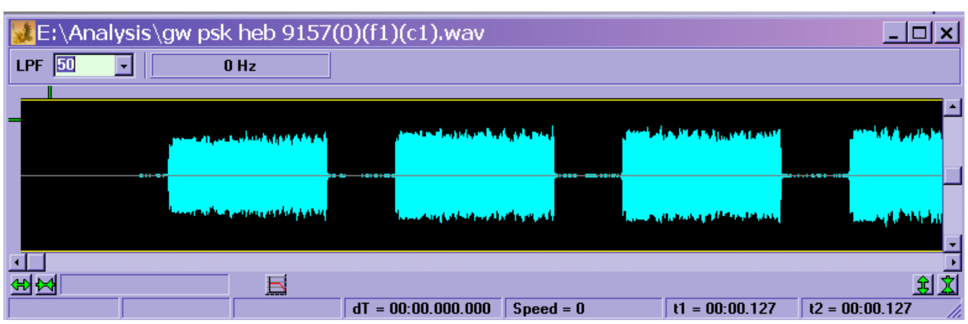
The first example deals with a burst mode relatively low speed QPSK system.



Load the signal and prepare for analysis. Examine the total captured .wav for a good section. Use the bandpass filter to delete the adjacent noise.

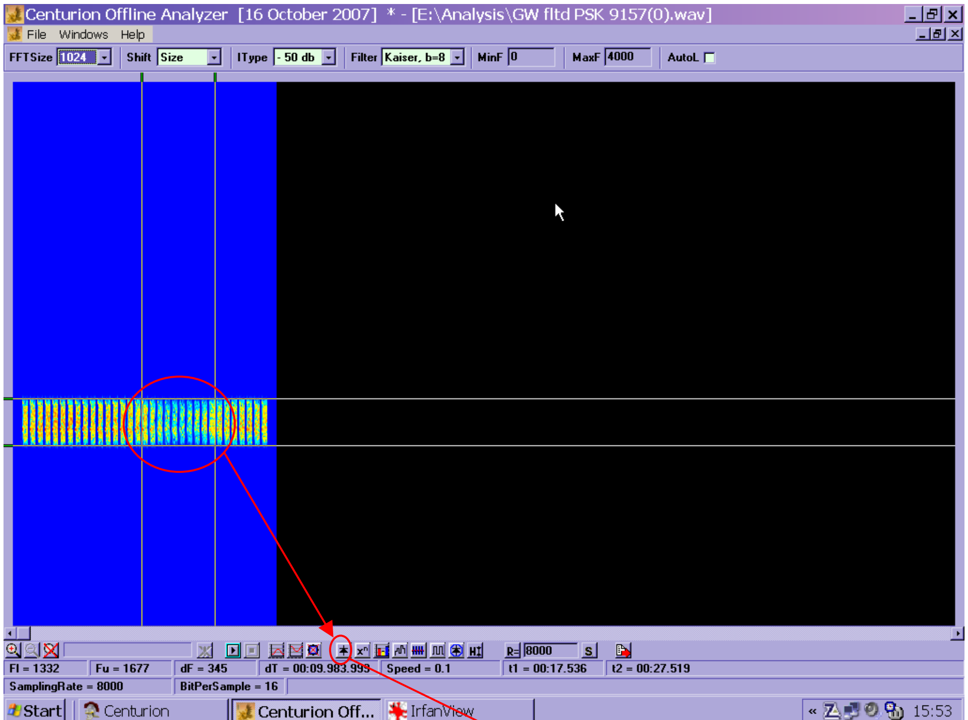


The signal has an opening spectral bandwidth (dF) of approximately 380 Hz. (limits 1303-1684Hz) and a center frequency of 2011 Hz. Create a working source file.



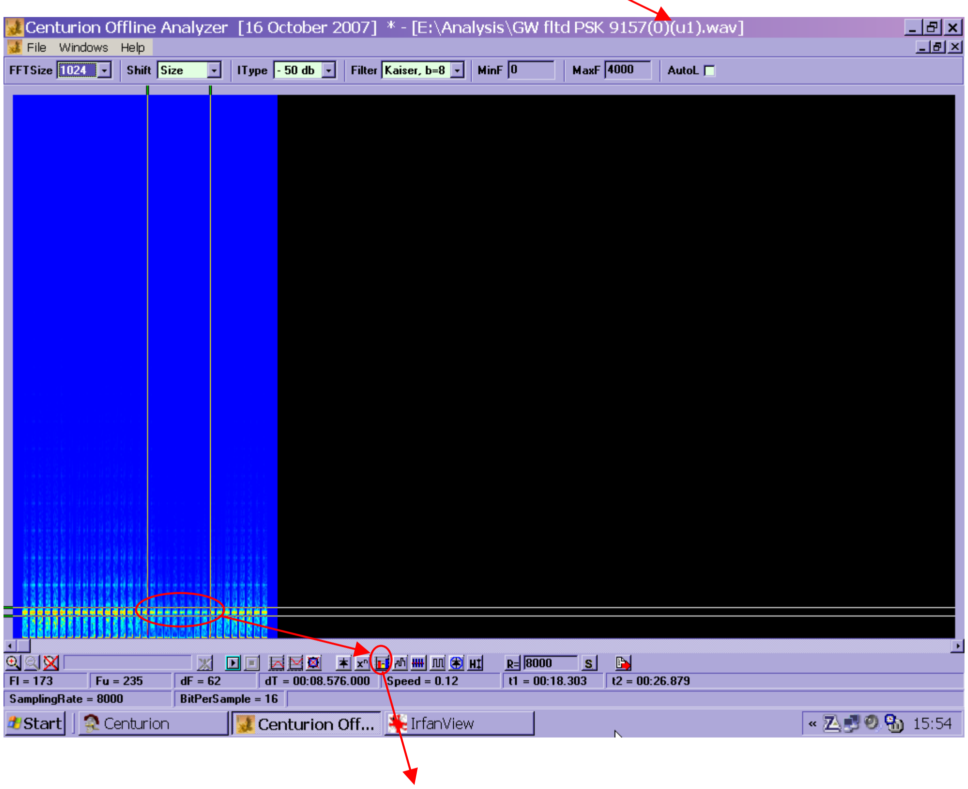
At this stage it is also worth noting the signal for general indications of noise, and for the relative SNR.

19.4.1 Symbol Rate



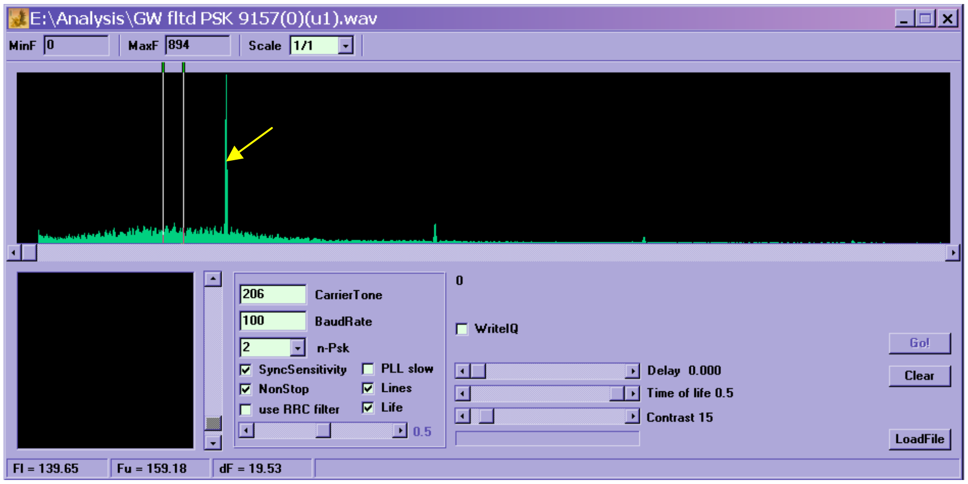
If required the Shift may be adjusted to expand the time axis.

Delineate a short section of good data and click the Quad Amplitude Detector button.

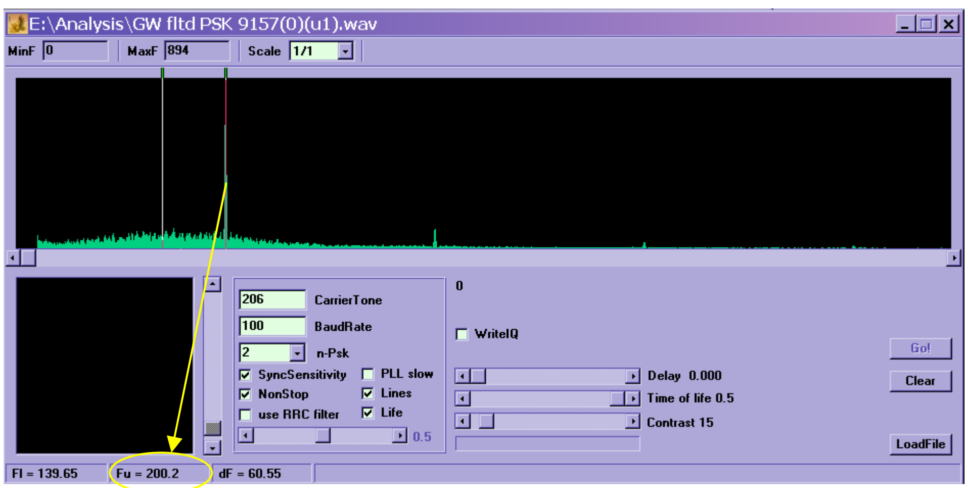


Note the baud rate/symbol rate row which has been produced in the **u** window

Delineate a section of some of these particularly where clear. The horizontal cursors should be fairly narrow as this helps to reduce noise in the next image. Click to call the High Resolution module.



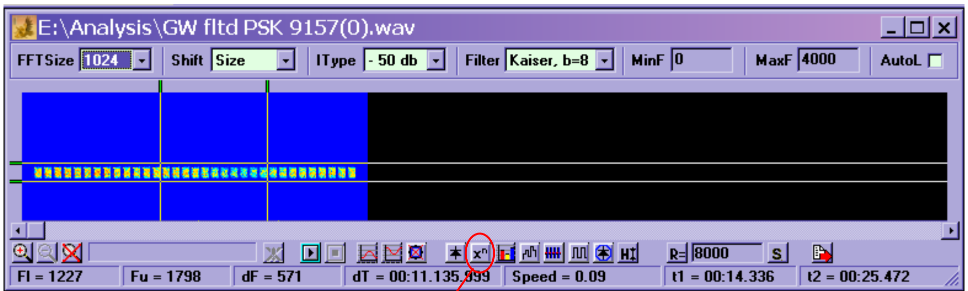
A spike is generated indicating the symbol rate.



Drag one of the vertical (time) cursors to align with this spike and read the rate.

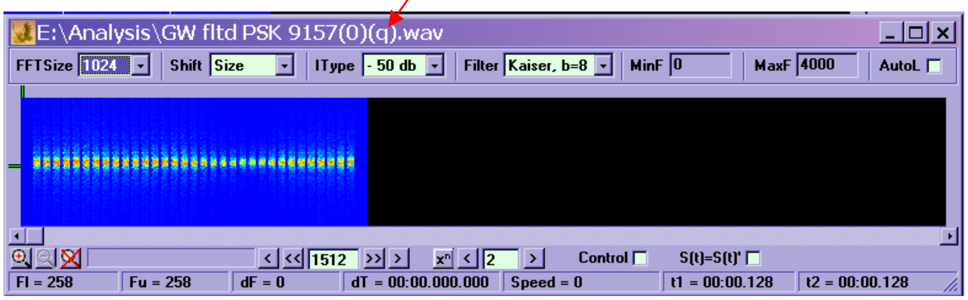
In this case 200 symbols/sec.

19.4.2 Determining n-ary (phases)



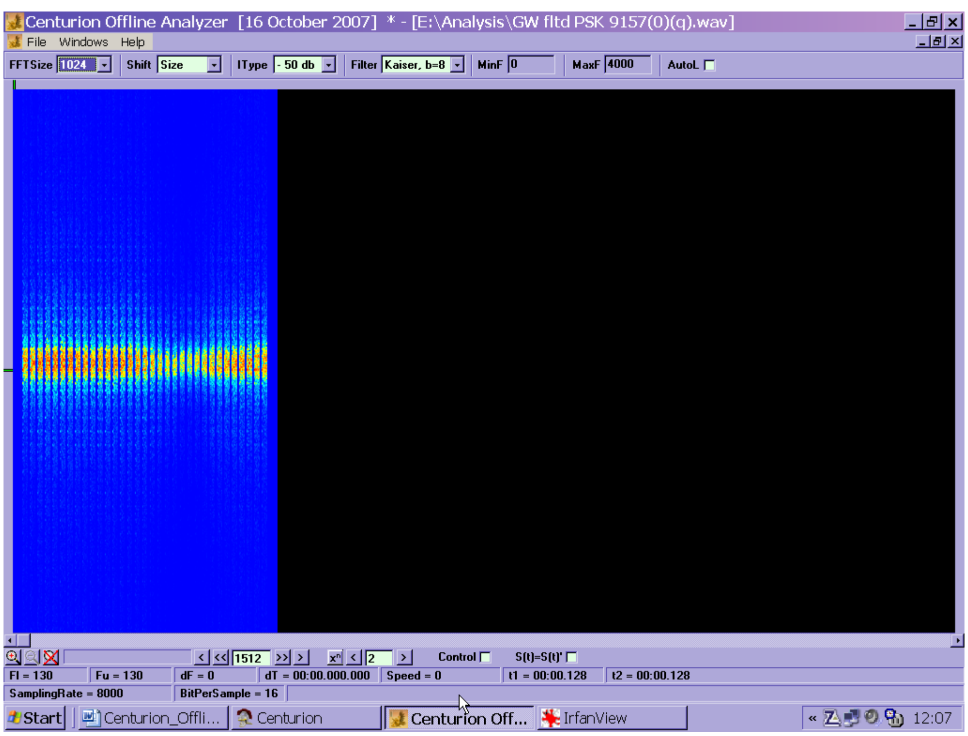
Select a few bursts in the source **(0)** window.

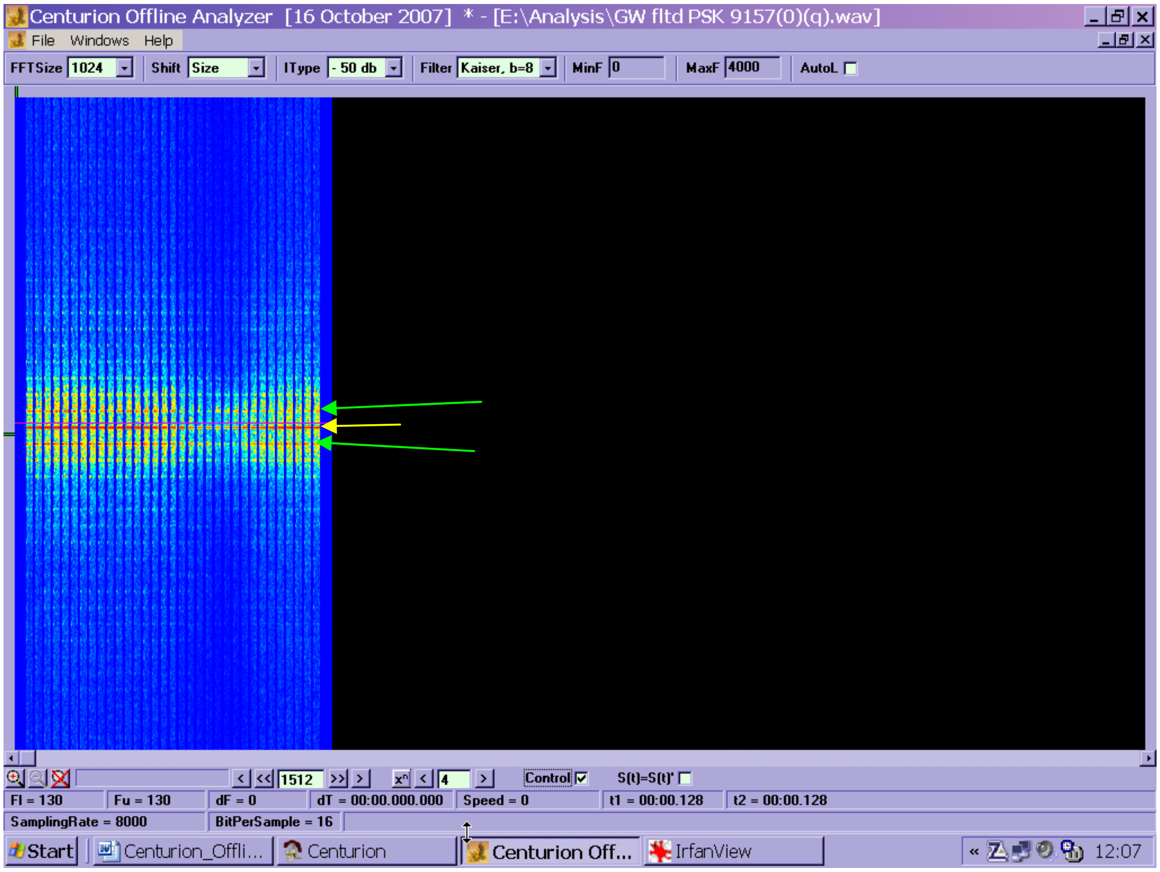
Click the involutions module button (X^n).



A new window is created with a **q** ID.

Maximise this window for better interpretation of the results.





On the previous image of the **q** window it will be noted that the phase count is at a default of 2 ie [S(t)^2]. Observing the results the analyst is looking for small bars as shown above in the primary (yellow) and secondary (light green) locations. These will only appear when the phase count equals the number of phases in the signal modulation.

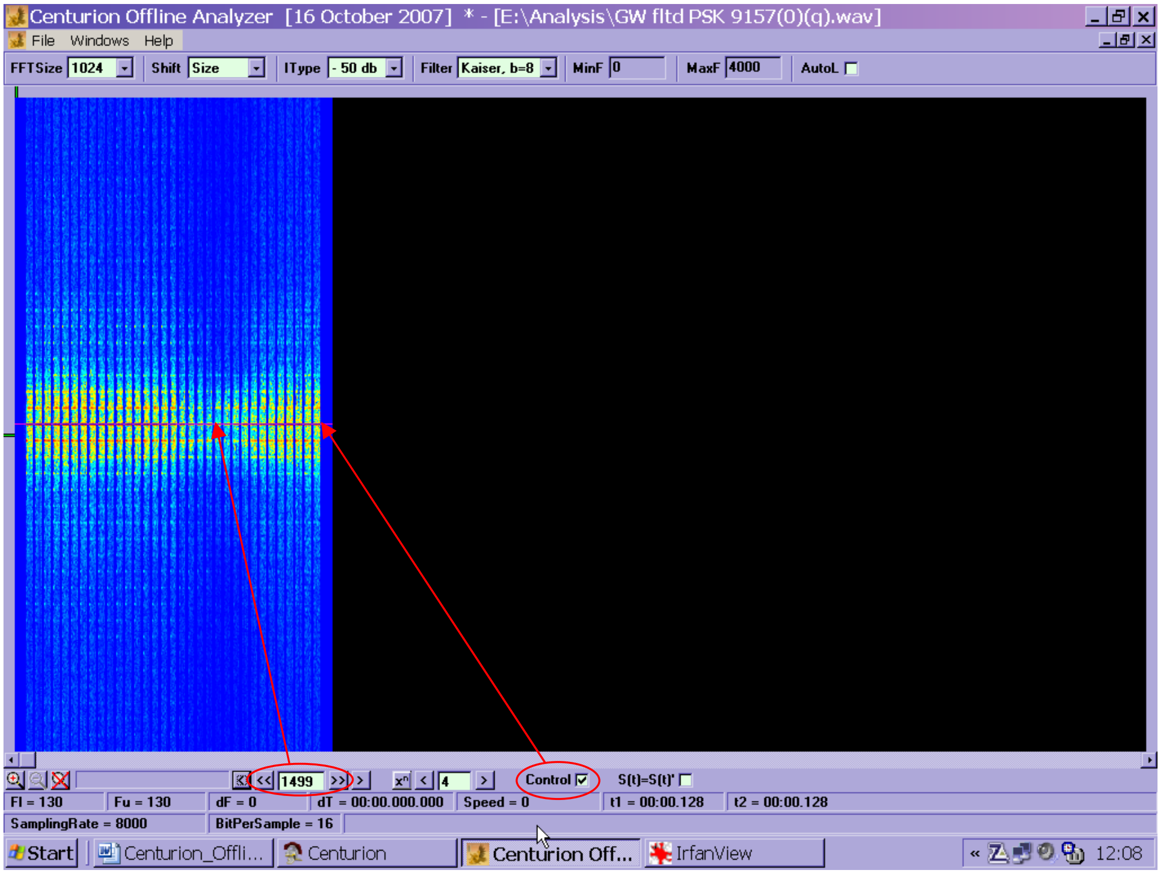
Determining is one of trial and error. Set the phase count in turn to the standard values of 2, 4, 8, and 16. After setting each value click the **X^n^** button to refresh the window with an updated result.

This example is a 4-ary PSK.

Do not cancel this window at this time but continue to the next subsection.

19.4.3 Determining sub-carrier (modulated tone) frequency.

Check the Control box to enable the horizontal red line

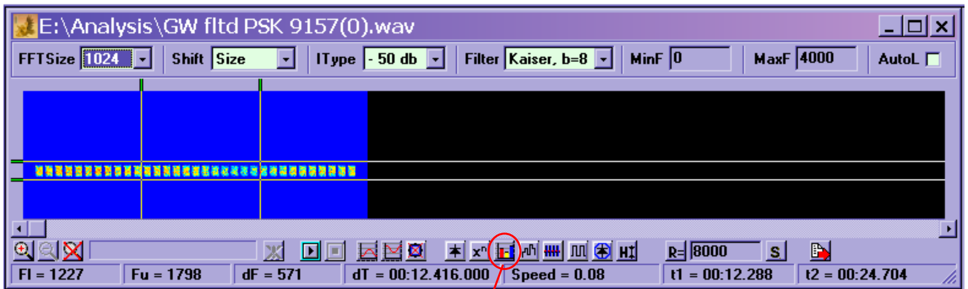


The frequency value of the red line is shown in the encircled box. If the signal bars and the line are not aligned as shown on the image on the previous page again it is a matter of trial and error to adjust the value and therefore the line position until they are. As before, after each adjustment the $\mathbf{X}^n$ button needs to be clicked to update the results.

When alignment is achieved the displayed value is that of the sub-carrier tone.

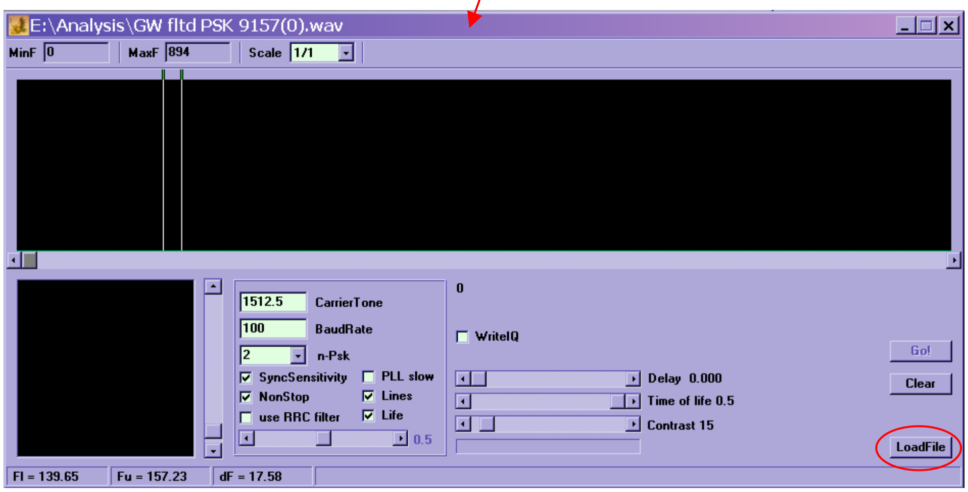
In this case it was found to be 1499 Hz.

19.4.4 Displaying phase constellation

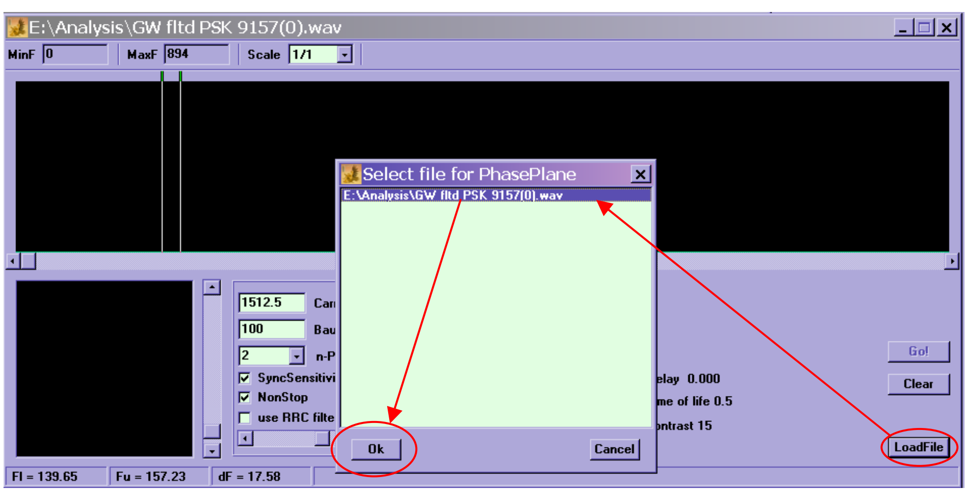


Prepare the signal. Select and area of signal.

Call the High Resolution module.



To activate the Phase Viewer click the LoadFile button.



A Select File Panel appears. Select the required file then click OK.

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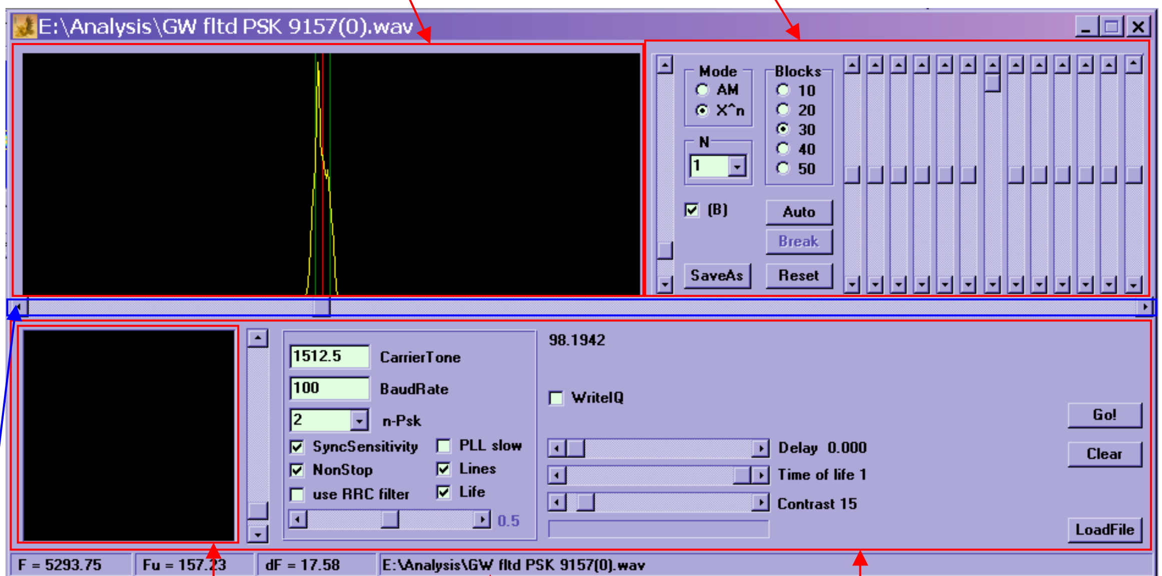
An amended viewer appears. Salient parts are described.

ISD corrector window.................................ISD controls.



Loaded file

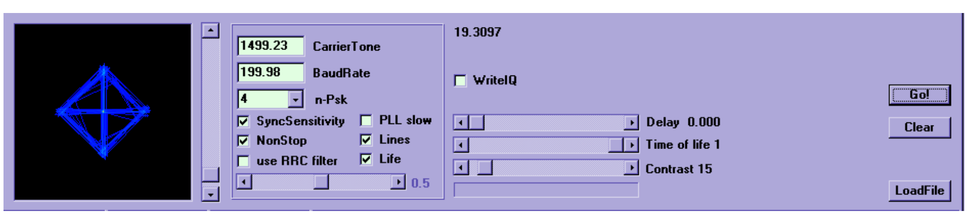
Constellation window

Phase viewer controls

Horizontal slider to position viewer relative to ends of loaded file.

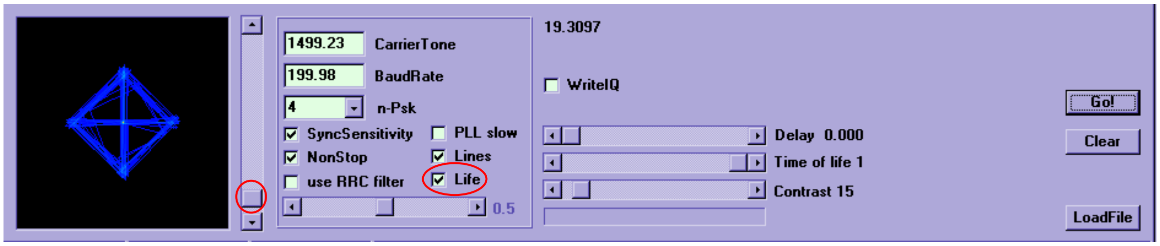
To run and create a constellation:

1. Enter the already determined parameters (as integers)
   Carrier Tone (4 digits),
   Baud (Symbol) Rate (5 digits),
   n-Psk (few selected values by dropmenu, or manually in the range 1-99).
2. Check boxes (Sync Sensitivity, NonStop, Life), and
3. Click the Go! Button.



The application runs continuously displaying progress and displaying the constellation in real-time (i.e. pulsing through the five bursts in this example), and the carrier tone and symbol rate values (entered as integers) will track to a finer value.

The constellation shows the modulation to be QPSK.



If the Life box is unchecked the data persists and builds in the phase plane window. At a suitable time (if allowed to continue too long saturation occurs) click the Break button and processing will stop. The constellation display will be retained.

The use of the SyncSensitivity/Lines checkboxes are discussed later in Section 19.11.4

If the amplitude (diameter) of the constellation is too small this can be increased by use of the vertical phase plane slider. The application must be running for this to take effect.

When in real-time display (Life checked) the persistence of the trace may be improved by use of the Delay and Time of Life controls.

The RRC Filter (Checkbox and slider) is discussed later in Section 19.9.5.6

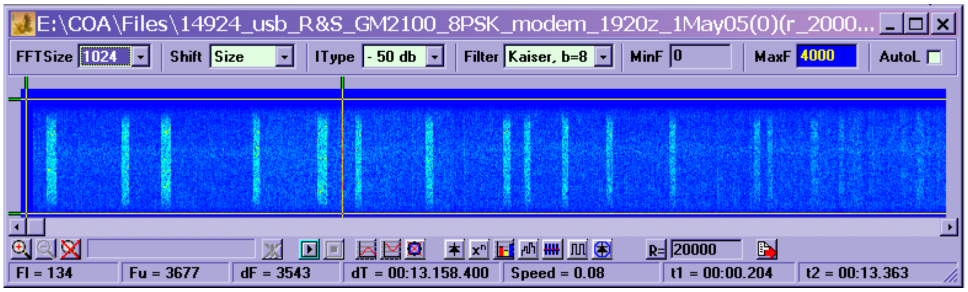
ISD Correction is discussed later in Section 19.5.5

19.4.5 PSK (1) Example Results

Summarizing:

Modulation:	QPSK (4-ary)
Mode:	Burst
Upper limit of spectrum:	~ 1685Hz
Lower limit of spectrum:	~ 1300Hz
Signal bandwidth of spectrum:	~ 385 Hz
Sub-carrier tone:	1500Hz
Symbol rate:	200 symb/sec
Maximum bit rate:	400 bps

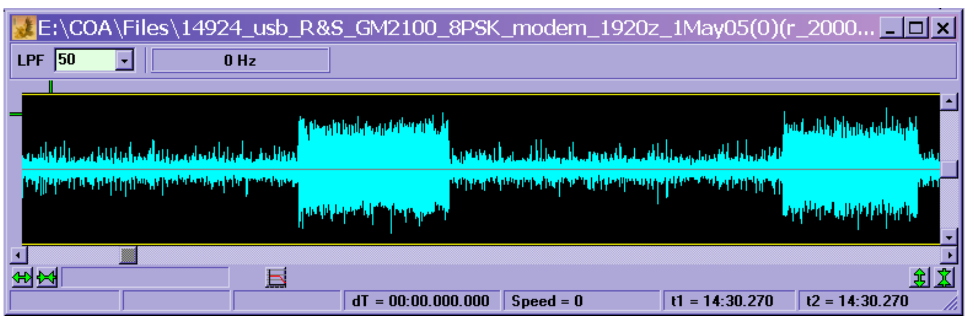
19.5 Analyzing PSK (2)



Load the signal and prepare for analysis.

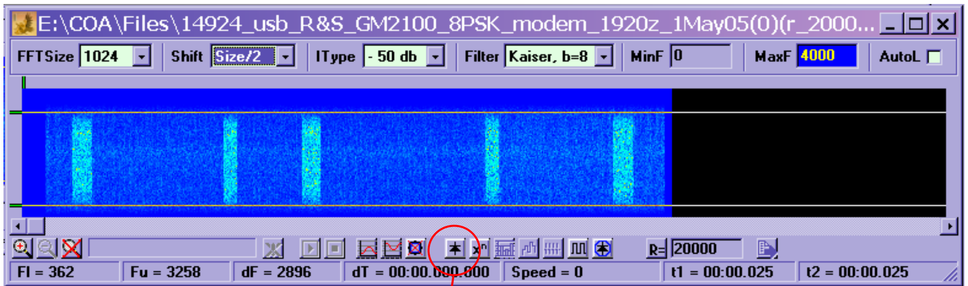
Examine the total for a good section and create a working version.

From this initial data it can be seen that the signal is one of PSK bursts, has opening approximation of 2896Hz spectrum bandwidth (limits 362-3258Hz) and a center frequency 1810Hz.



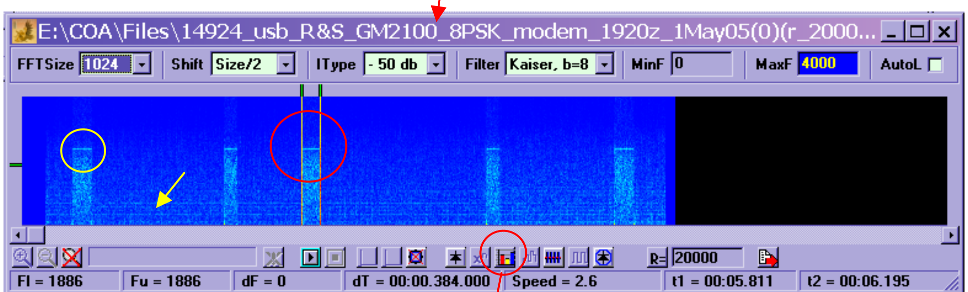
At this stage it is also worth noting the signal for general indications of noise and for the relative SNR.

19.5.1 Symbol rate.



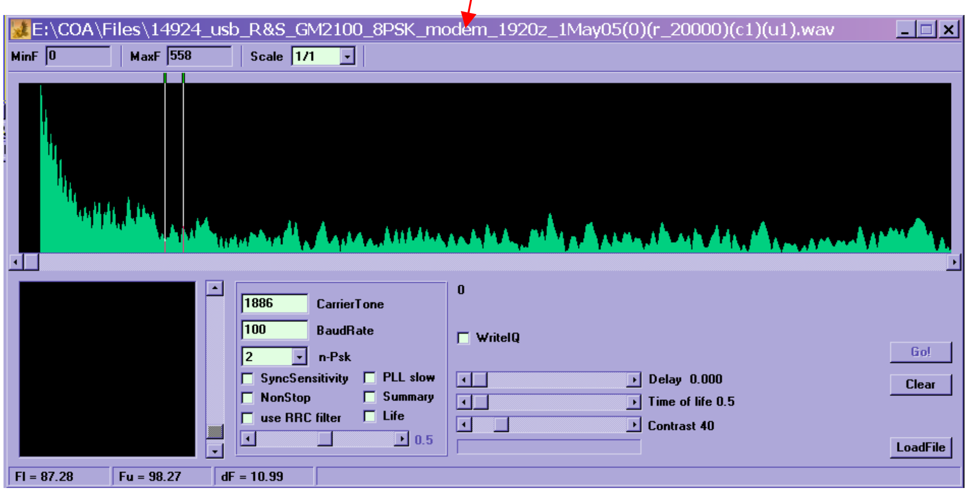
The Shift is adjusted to expand the time axis.

Click the Quad Amplitude Detector button.

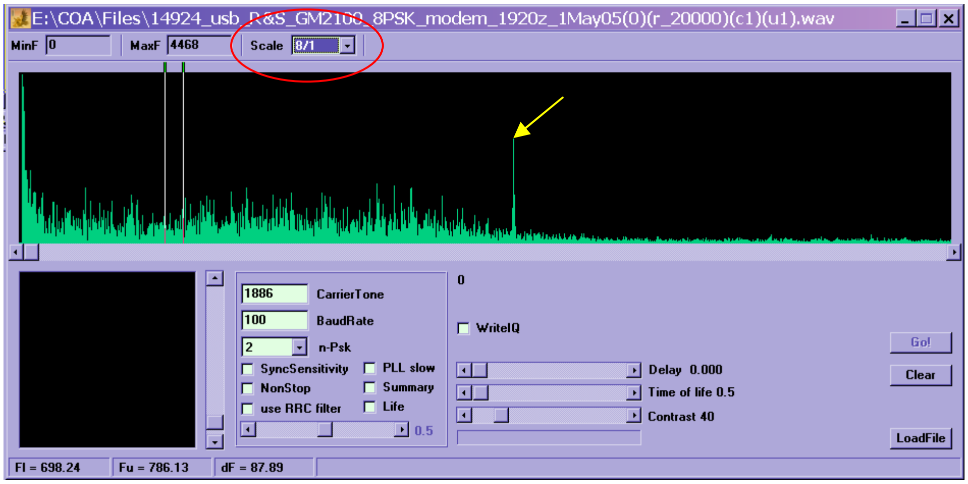


Note the Symbol Rate line at the top of each burst, and the inter burst noise.

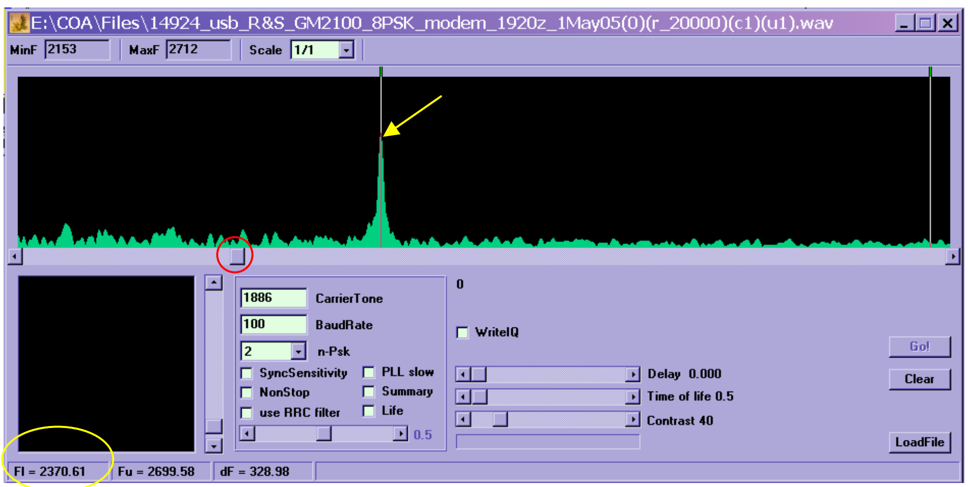
Set the vertical time markers at the extremities of one of these rate lines. Click to call the High Resolution module.



This image appears to lack any relevant data.



Adjust the Scale value until a spike appears, or

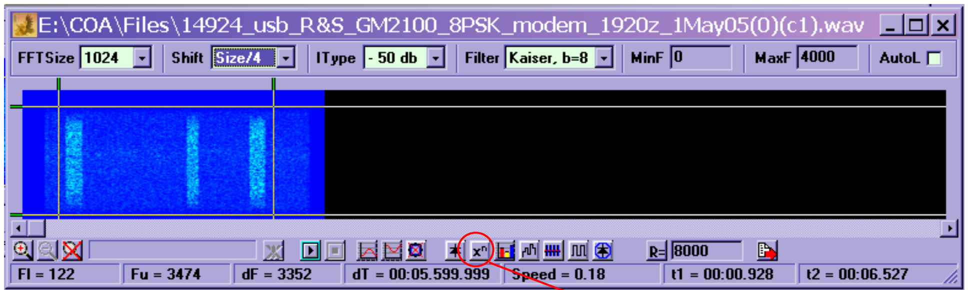


Alternatively, adjust the horizontal slider until the spike becomes visible.

Whichever method (or both) is used align one (e.g. Fl) of the vertical time markers with this spike and read the Symbol rate from the associated box in the status line.

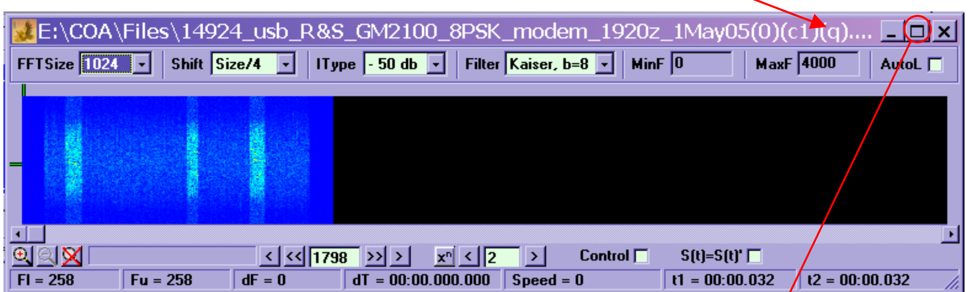
In this example the Symbol Rate = 2371 sym/sec.

19.5.2 Determining n-ary (phases)



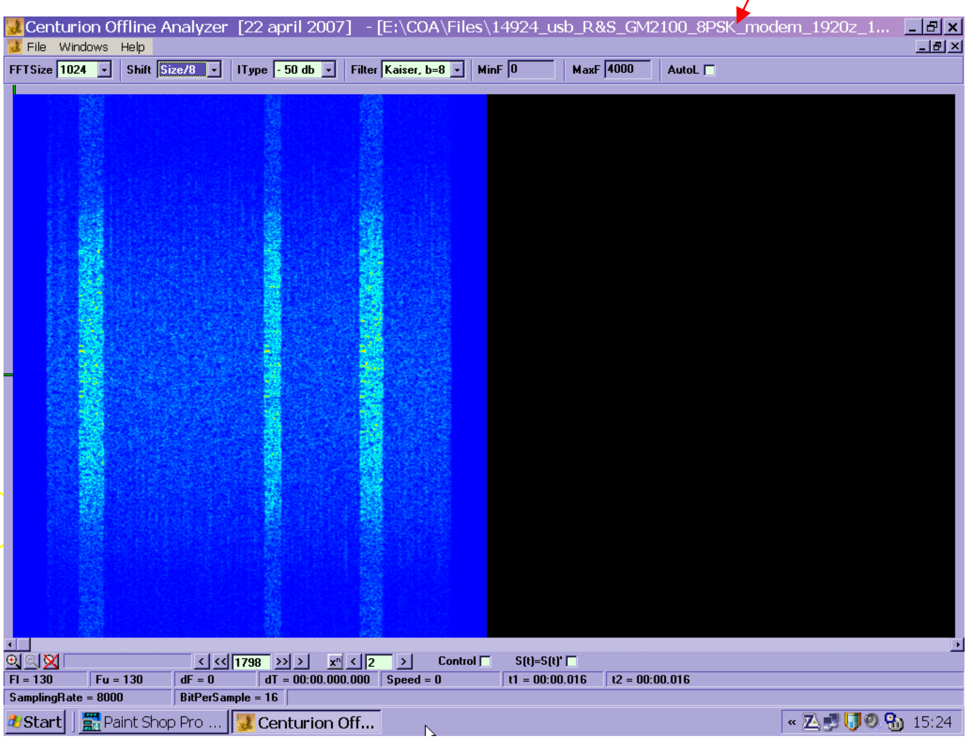
Select a few bursts in a copy window.

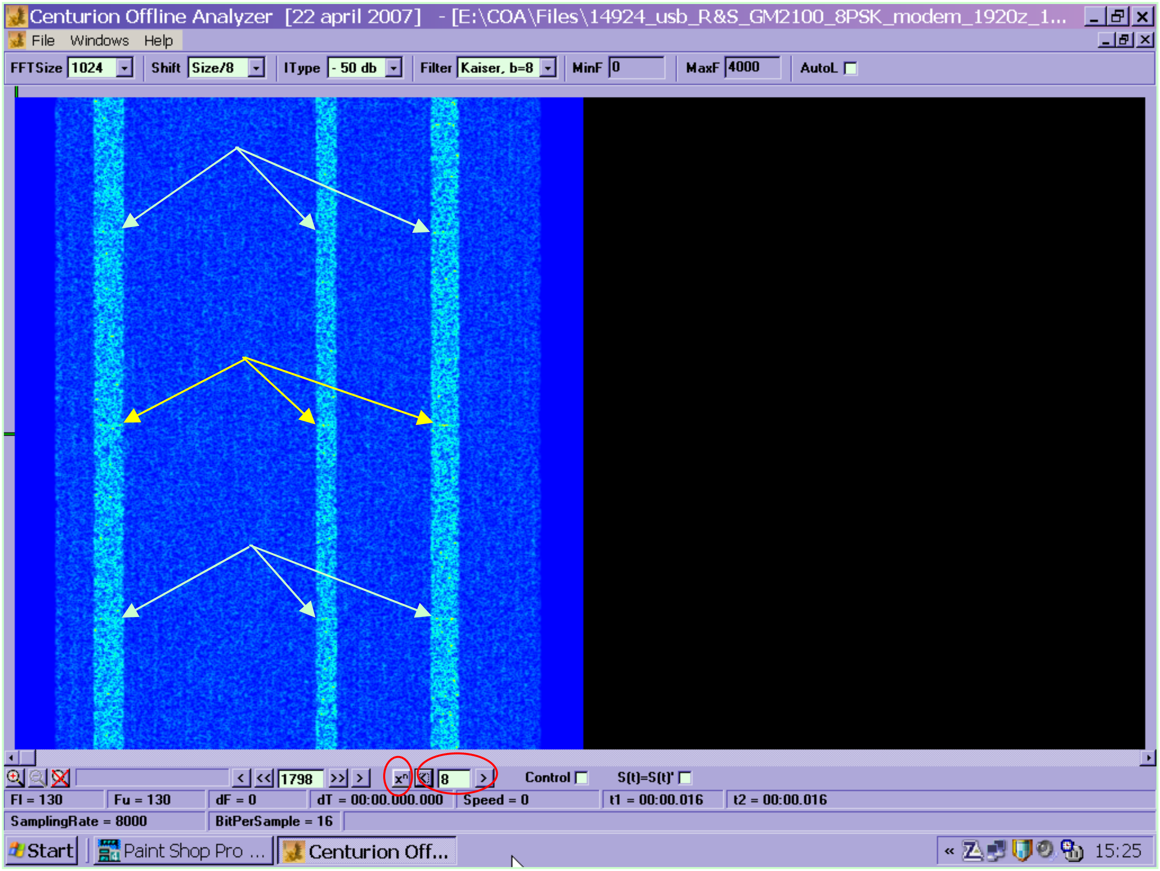
Click the Involutions module button (X^n).



A new window is created with a **q** ID.

Maximize this window for better interpretation of the results.





On the previous image of the **q** window it will be noted that the phase count is at a default of 2 ie [S(t)^2]. Observing the results the analyst is looking for small bars as shown above in the primary (yellow) and secondary (light green) locations. These will only appear when the phase count equals the number of phases in the signal modulation.

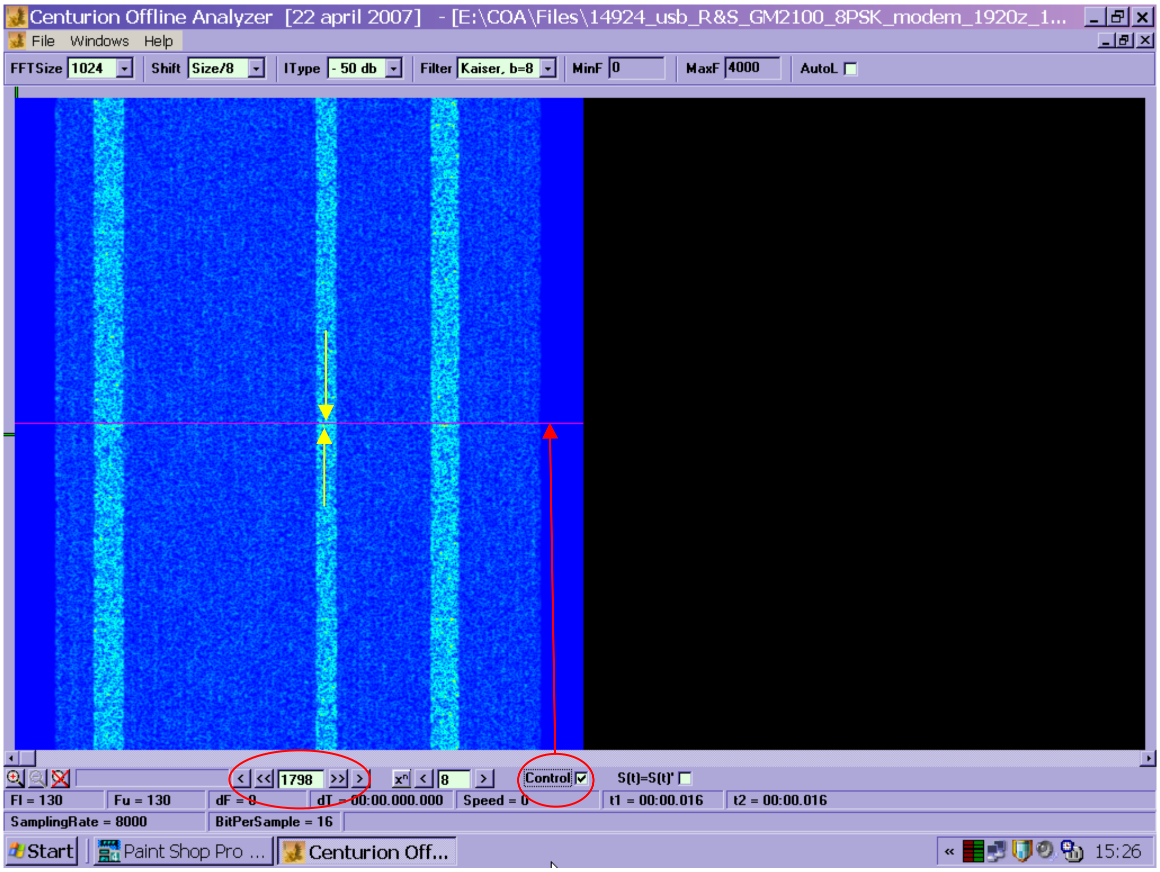
Determining is one of trial and error. Set the phase count in turn to the standard values of 2, 4, 8, and 16. After setting each value click the **X**^{n} button to refresh the window with an updated result.

This example is an 8-ary PSK.

Do not cancel this window at this time but continue to the next subsection.

19.5.3 Determining sub-carrier (modulated tone) frequency.

Check the Control box to enable the horizontal red line.

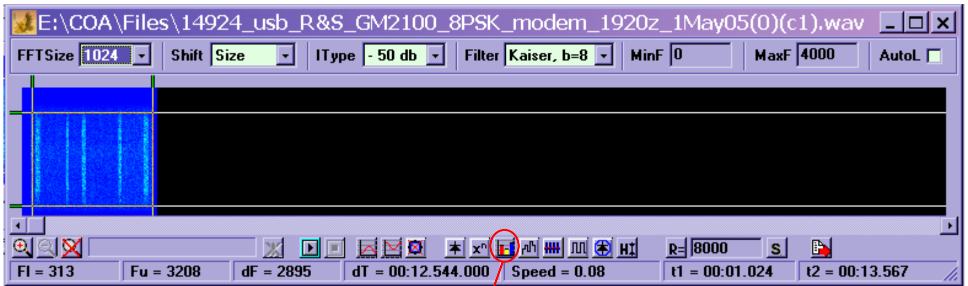


The frequency value of the red line is shown in the encircled box. If the signal bars and the line are not aligned again it is a matter of trial and error to adjust the value and therefore the line position until they are. As before, after each adjustment the $\mathbf{X}^n$ button needs to be clicked to update the results.

When alignment is achieved the displayed value is that of the sub-carrier tone.

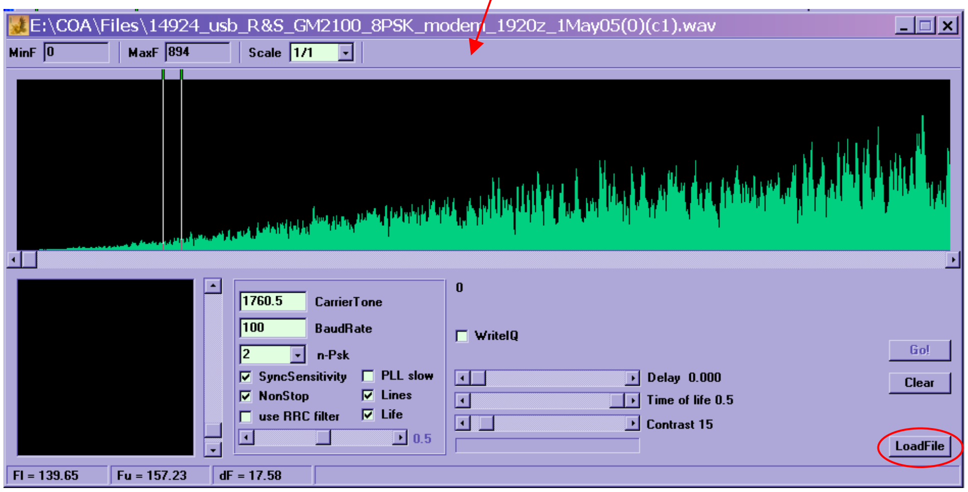
In this case it was found to be 1794 Hz (not illustrated).

19.5.4 Displaying phase constellation.

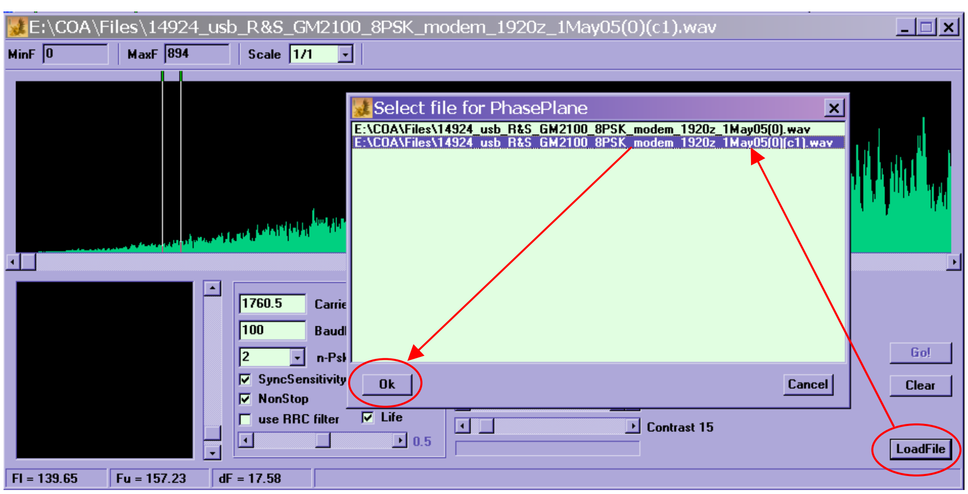


Prepare the signal. Select an area of signal.

Call the High Resolution module.

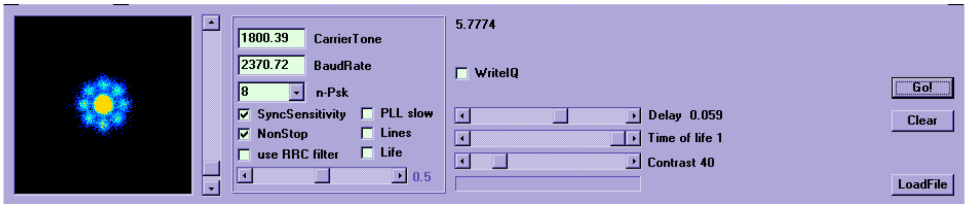


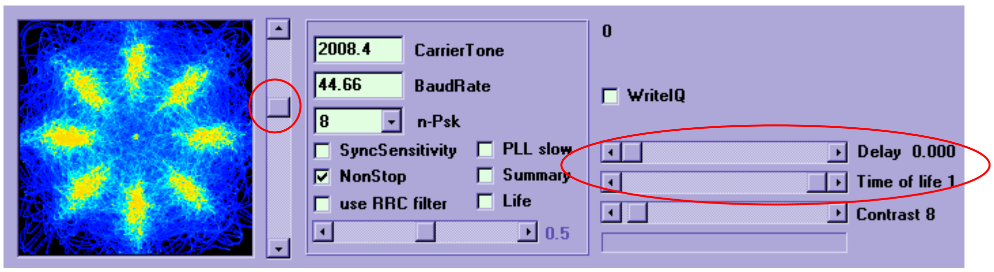
To activate the phase viewer click the LoadFile button.



A Select File panel appears. Select the required file then click OK.

Alternatively, if the Life box is unchecked the data persists and builds in the phase plane window. At a suitable time (if allowed to continue too long saturation occurs) click the Break button and processing will stop. The constellation display will be retained.



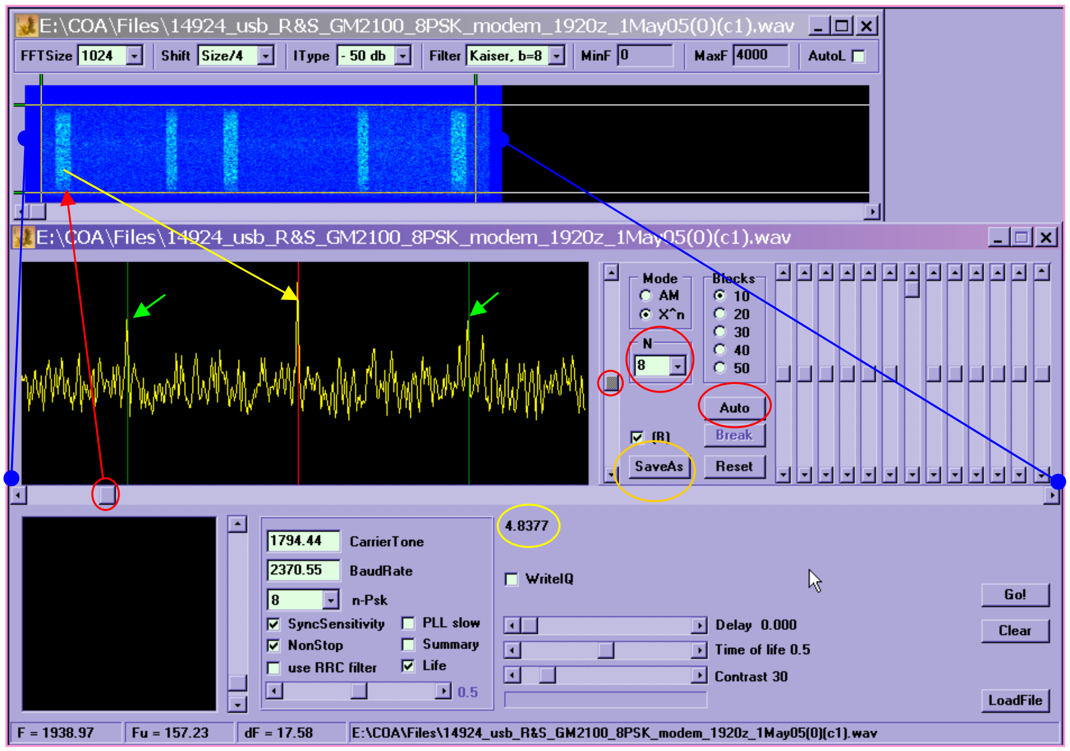


If the amplitude (diameter) of the constellation is too small this can be increased by use of the vertical phase plane slider. The application must be running for this to take effect.

When in real-time display (Life checked) the persistence of the trace may be improved by use of the Delay and Time of Life controls.

19.5.5 Use of ISD (Inter-Symbol Distortion) correction

In respect of the first of the previous two images with a signal using very short bursts, and/or having a poor SNR ratio it is possible to use ISD correction to effect some improvement.



The horizontal slider represents the pointer to the data in the current parent file and which will appear in the ISD window. As the slider passes into the data area three spikes rise in the window at the red and green lines. The slider should be positioned to achieve maximum spike amplitude. The vertical slider should be adjusted to achieve a suitable working height.

The N control is set to the previously measured n-ary value.

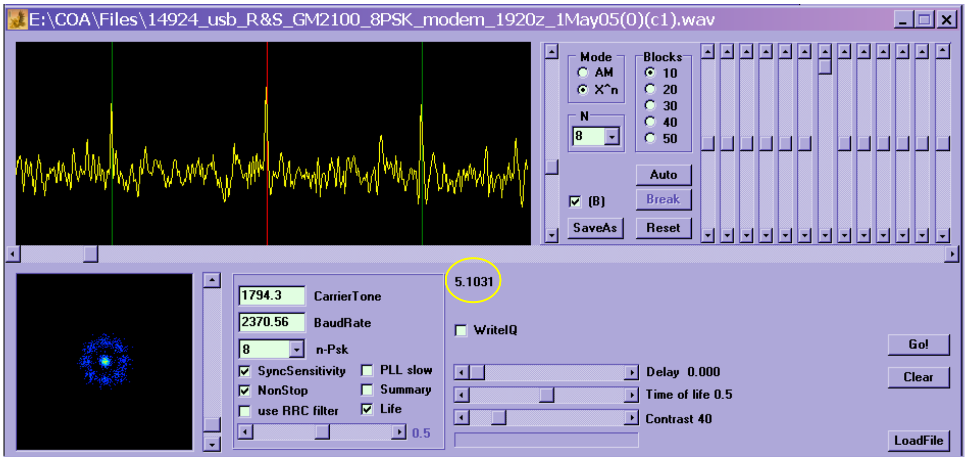
Previously 0, the SNR value now appears in the yellow ellipse.

Clicking the Auto button initiates the process which should be allowed to complete. Test the new value by clicking the Go! button after each update. Note that Auto may also be checled even although Go! is active in the lower section.

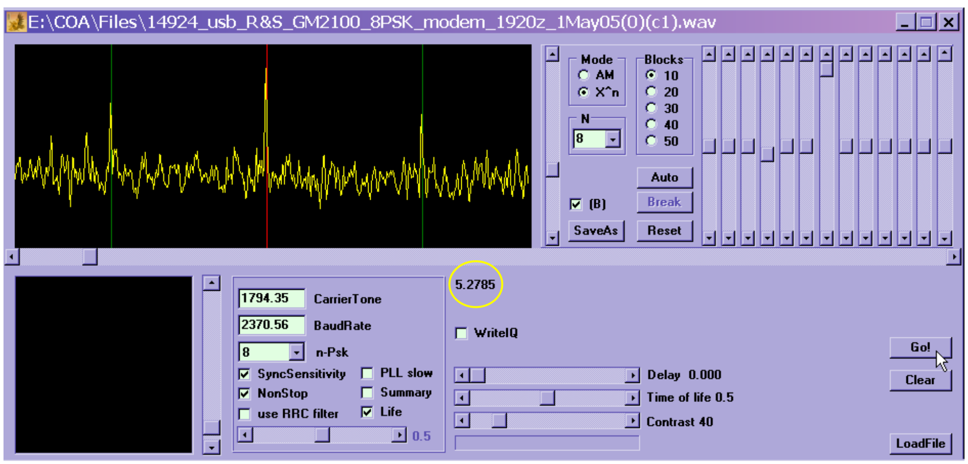
The target for SNR is >=9-10 but with deficiencies in the recorded signal may not be achieved.

SaveAs creates a new file from the new calculations but it is essential not to do this until necessary since the signal will disappear from the module.

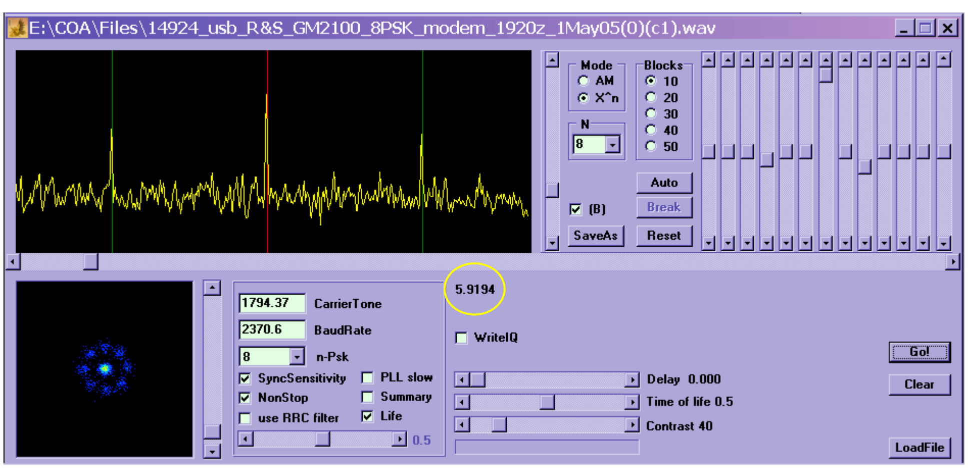
Note that ISD is correction is for high speed PSK signals (>= ~150-200 symb/sec).



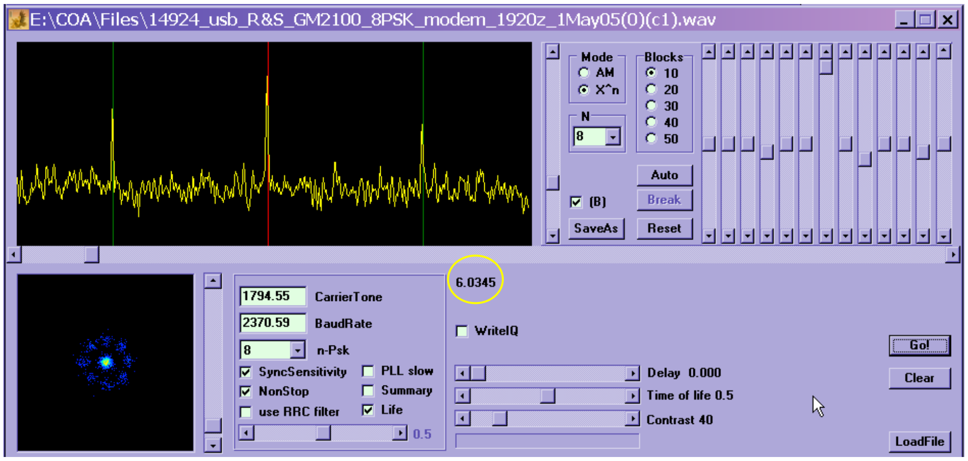
After Pass 1 the SNR= 5.1031



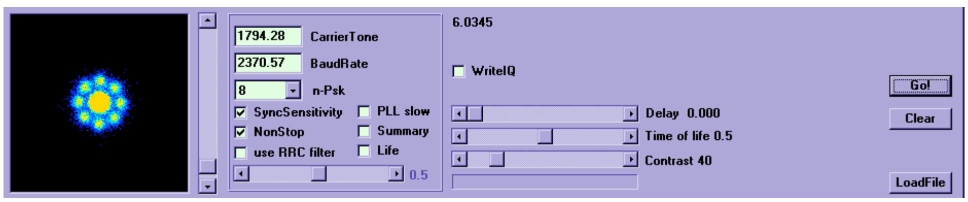
After Pass 2 the SNR=5.2785



After Pass 3 the SNR=5.9194

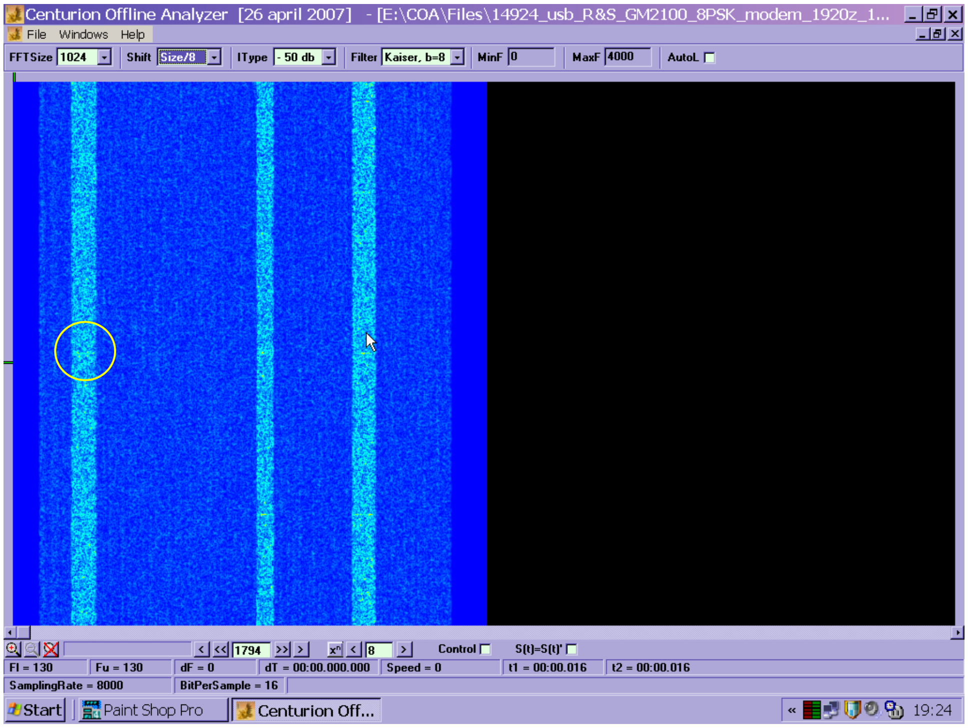


After Pass 4 the SNR=6.0345



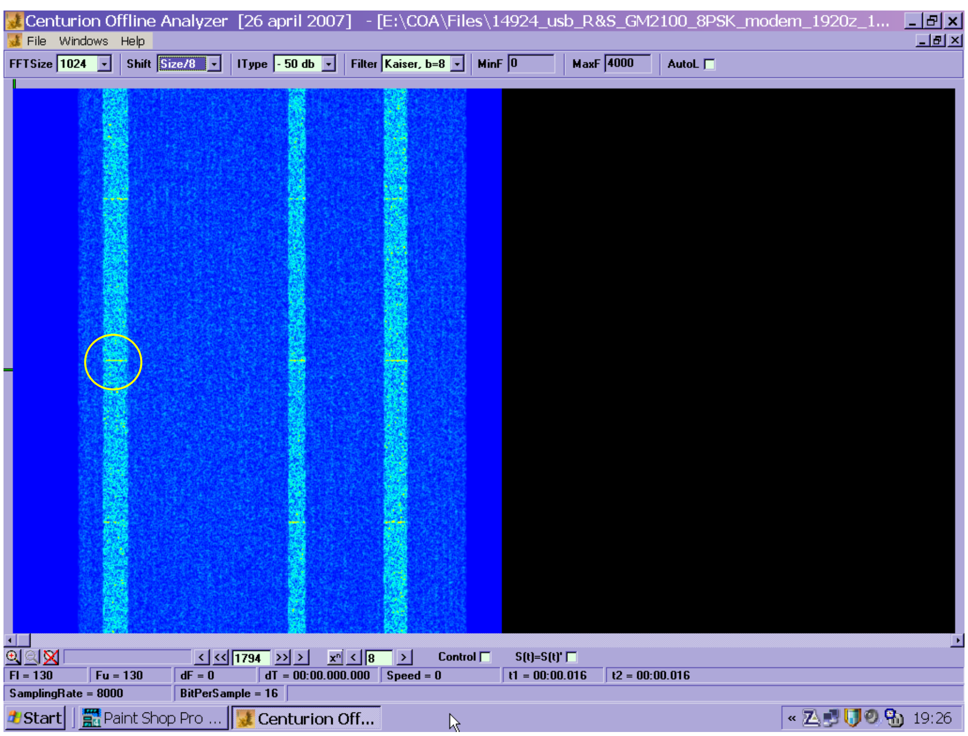
This is the constellation created with Life unchecked.

19.5.6 Comparison of ISD corrected and Original files.



Original file.

Spectral lines are barely discernable.



Corrected file

The spectral lines are much more discernable.

19.5.7 PSK (2) Example Results

Summarizing:

Modulation:	8-ary PSK
Mode:	Burst
Upper limit of spectrum:	~3258Hz
Lower limit of spectrum:	~362HZ
Signal bandwidth of spectrum:	~2896Hz
Sub-carrier tone:	1794Hz
Symbol rate:	2371 sym/sec.

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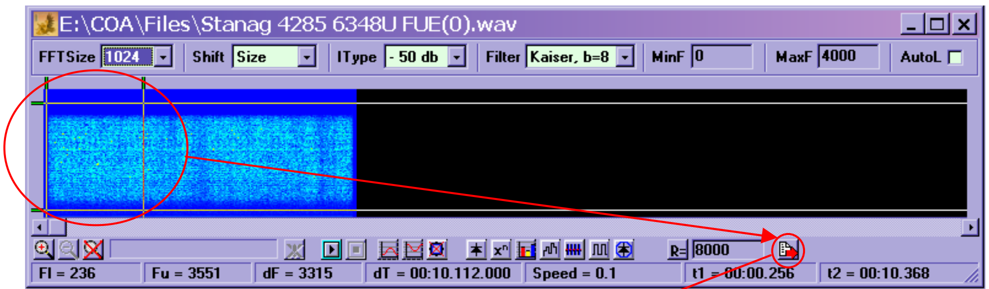
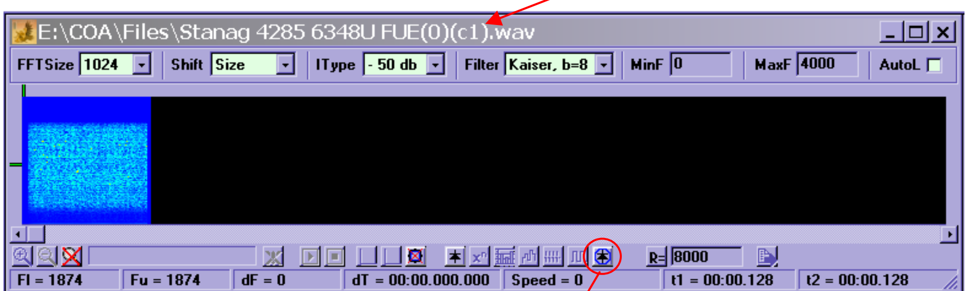
19.6 Analyzing PSK (3)

This is a third worked example showing a continuous signal with high symbol rate.

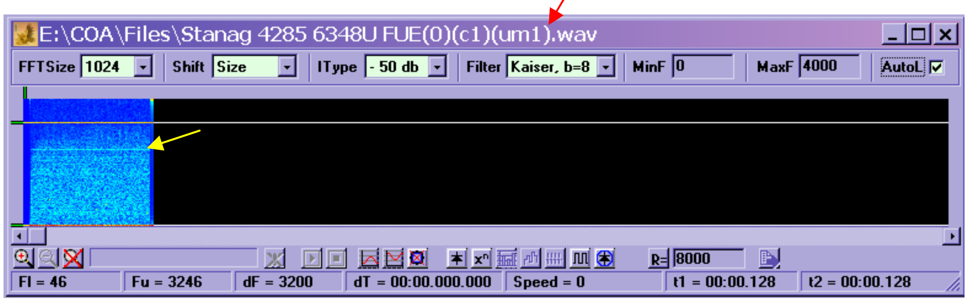
19.6.1 Symbol rate.



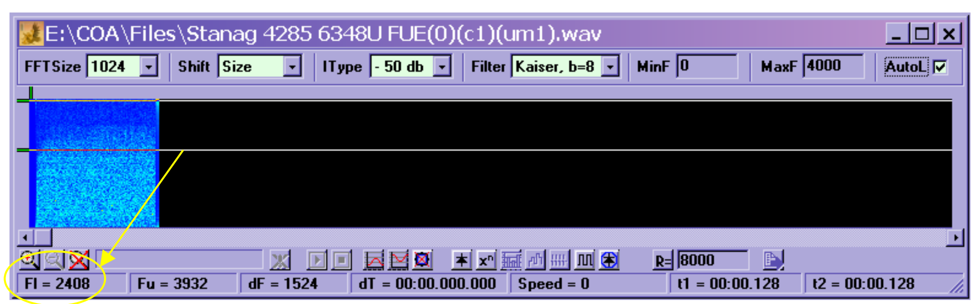
Prepare the signal. Delineate a section of good signal and copy.



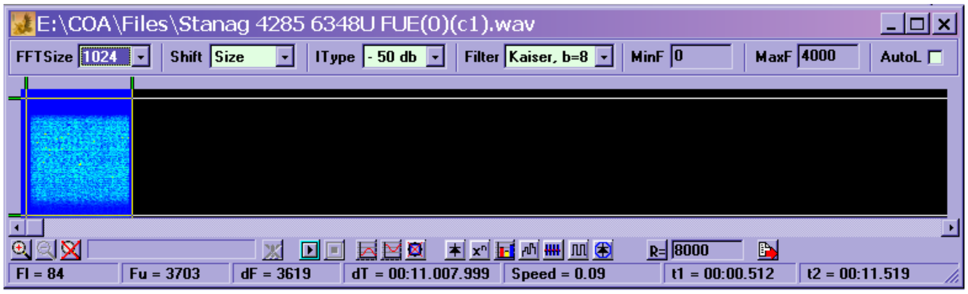
Call the Modified Quad Amp Det module.



In the **um** window can be seen the symbol rate line.

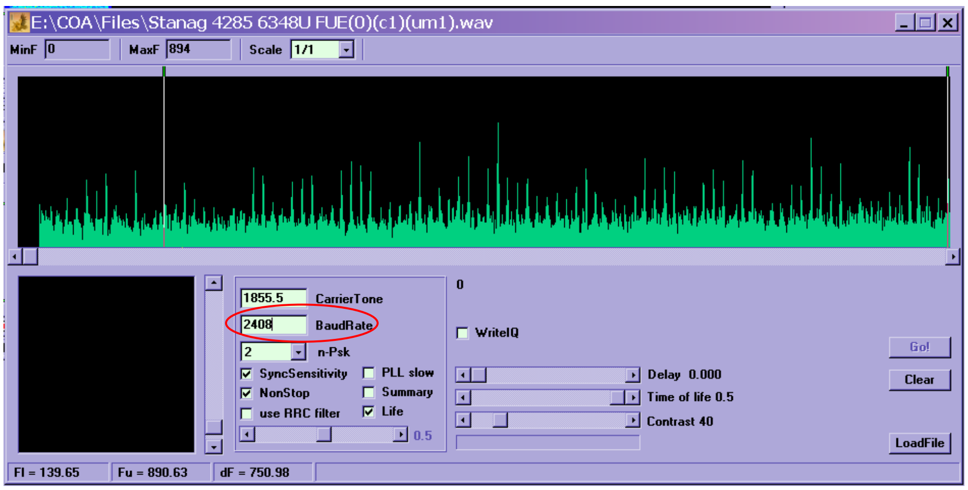


The rate can be measured by aligning one of the horizontal markers.
Here Fl = 2408
This is the Symbol Rate.

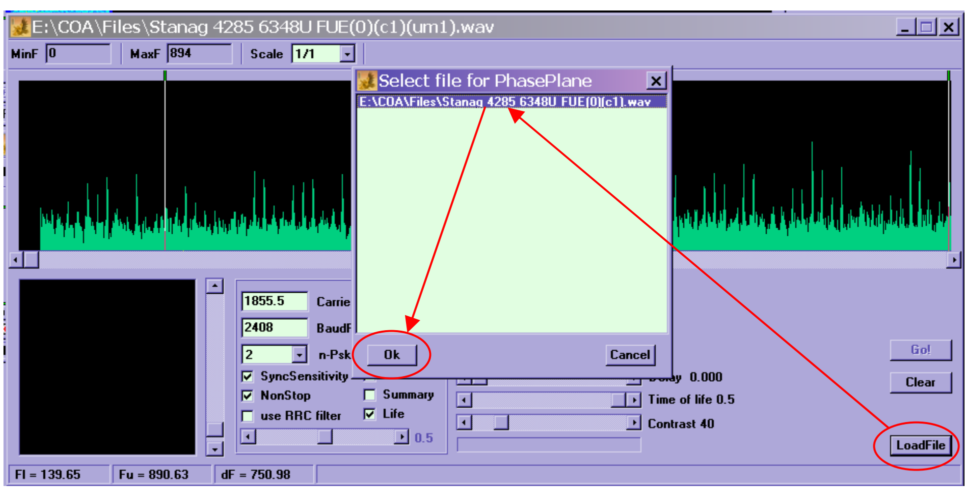


Return to source copy **c.**

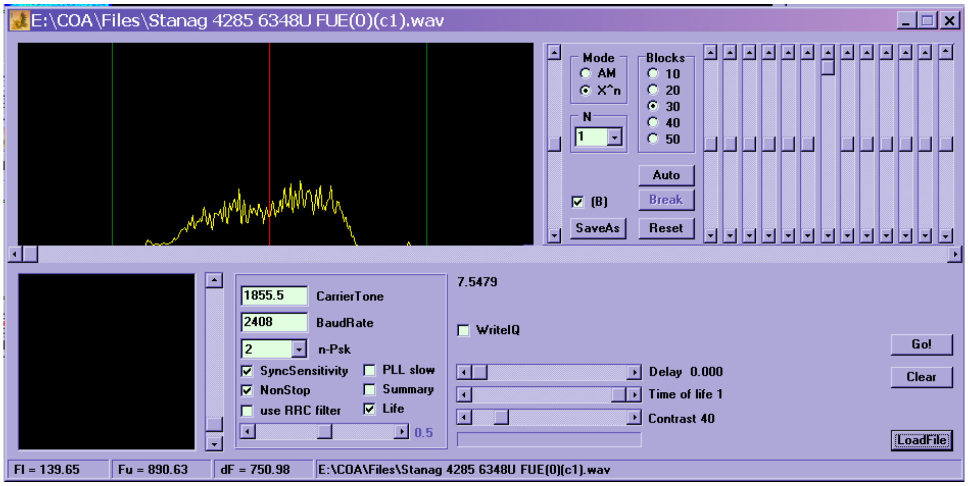
Delineate and call Phase Viewer module.



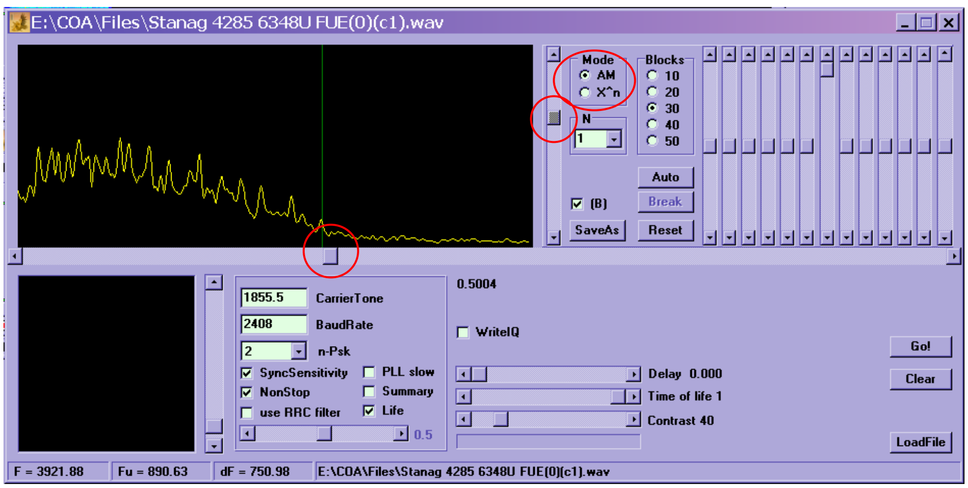
Enter the Symbol rate measured above into the Baud Rate



Call LoadFile and select the file.

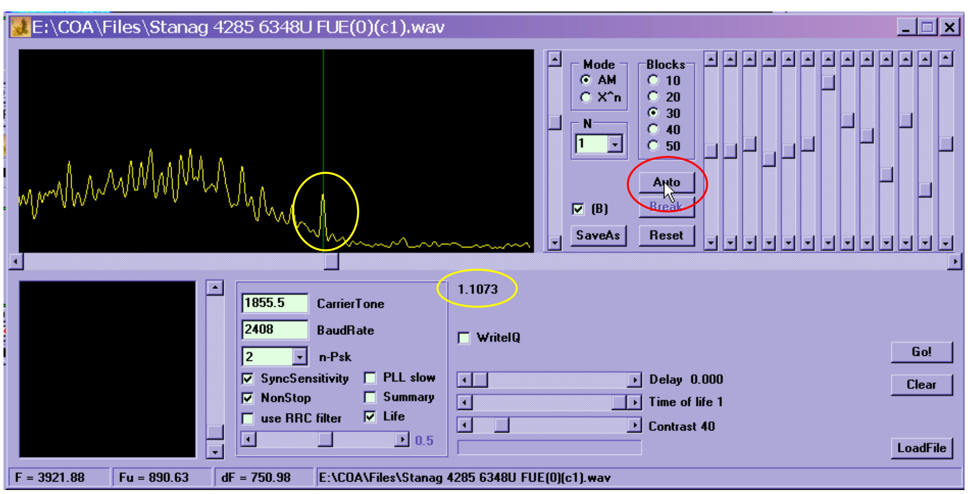


The ISD panel appears.



Set Mode to **AM**.

Adjust horizontal slider for maximum signal and vertical slider for about mid height of signal.



Execute AUTO a few times until the value stops varying (mostly increasing).

Note the rising peak at the green marker.

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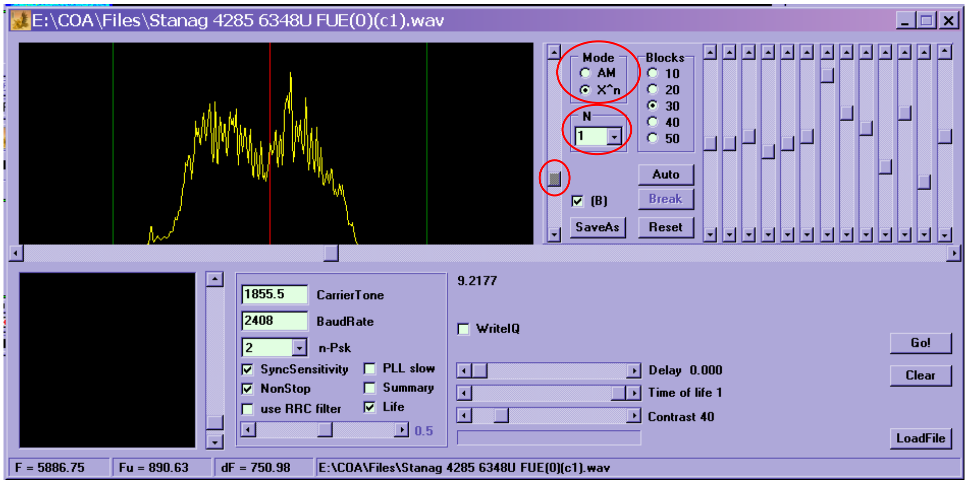
19.6.2 Determining N-ary.

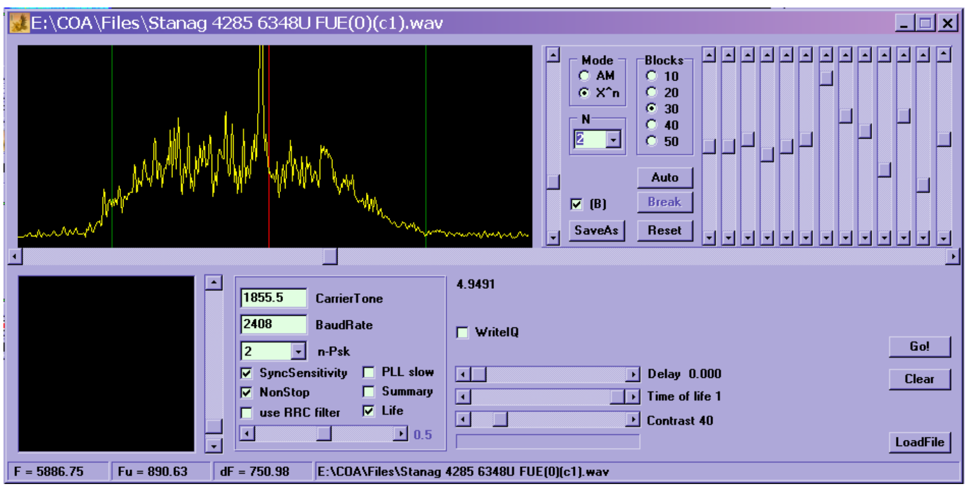


Select **X^n** Mode.

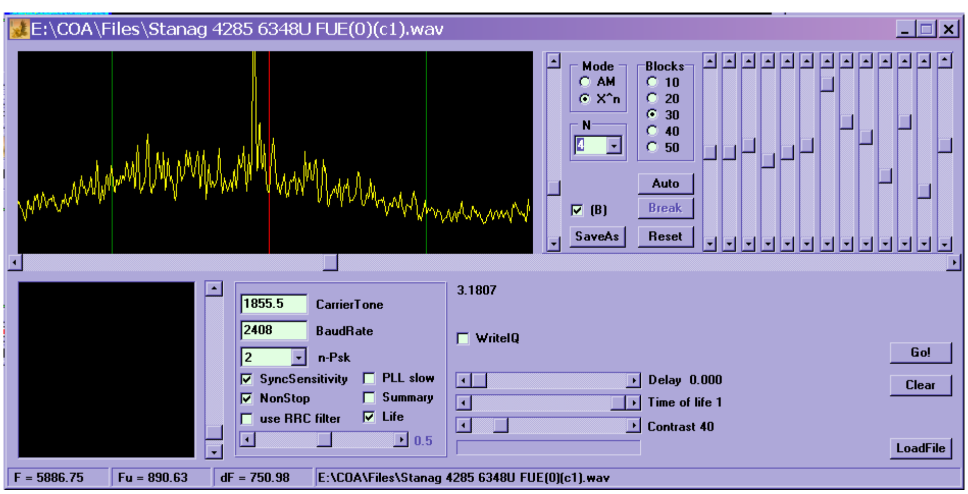
Adjust vertical slider to set signal height.

Test N= 1-16 until one achieves a set of clear lines.

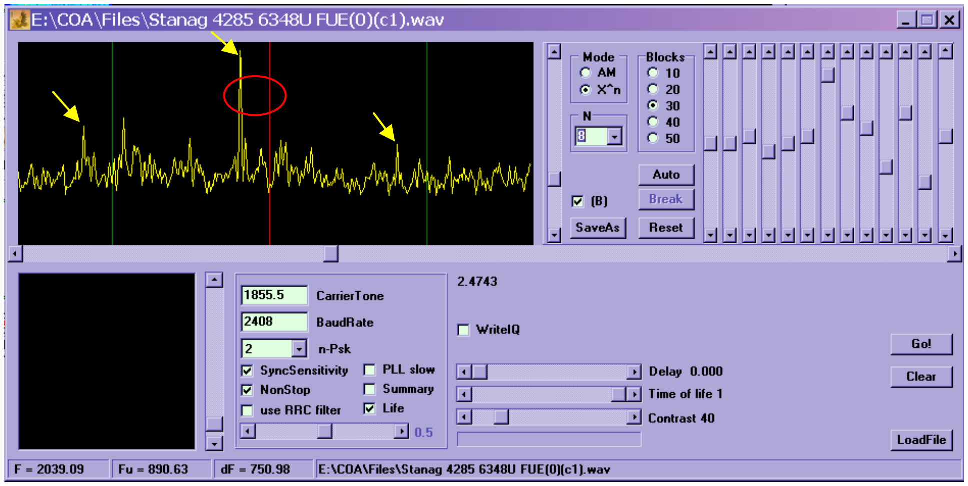
N=1



N=2



N=4

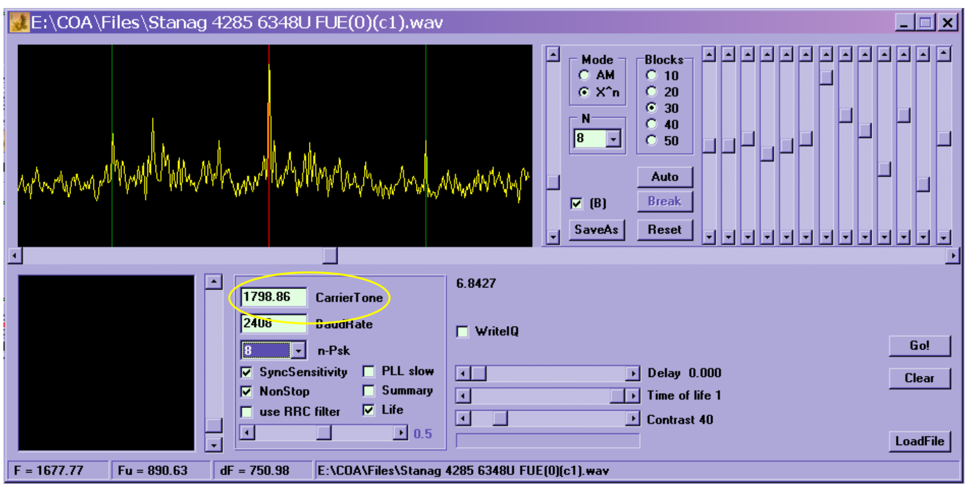


N=8
Clear lines. Therefore signal is 8-ary.

The signal lines are likely to be offset from the red/green markers.

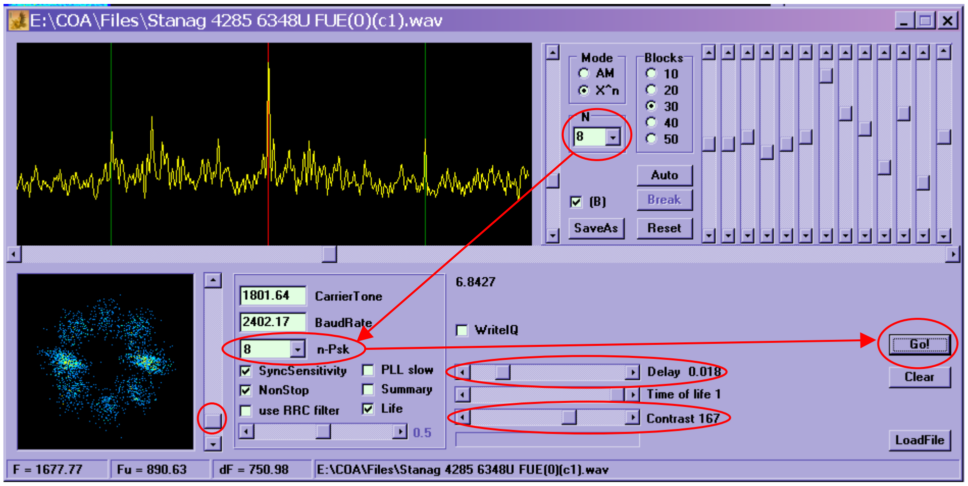
Click the signal line nearest the red line.

19.6.3 Determining sub-carrier (modulated tone) frequency.



Both should align.
Note the adjacent signal lines will also be aligned with the green markers.
The carrier tone will now be approximately the signal's sub-carrier frequency(1800Hz).

19.6.4 Displaying phase constellation

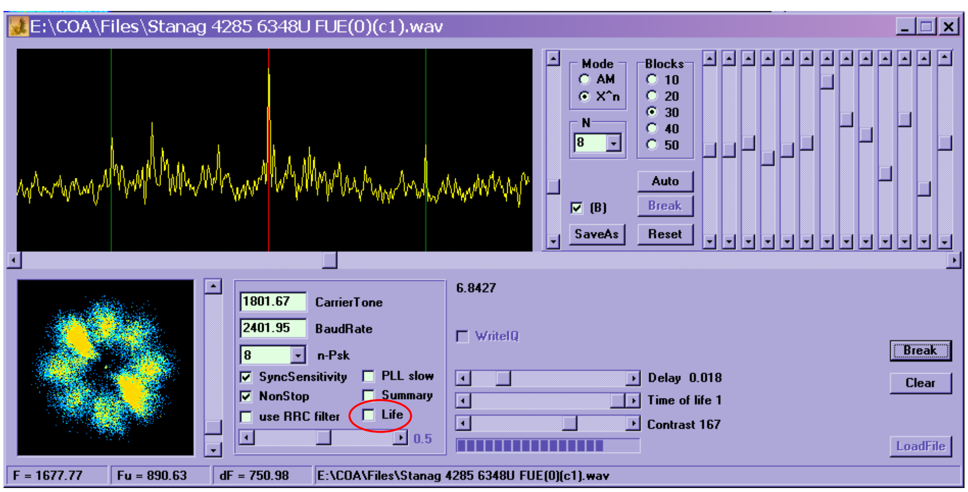


Set n-PSK to the earlier determined N value.

Click Go! to run and display the constellation.

Adjacent to the constellation window adjust the vertical slider to achieve a suitable constellation diameter. Adjust the Contrast and Delay sliders to sharpen the display.

Note the Carrier Tone and BaudRate (SymbolRate) will update.



Alternatively uncheck the Life box to build the constellation (as per a storage scope) clicking the Break button when sufficiently clear.

The constellation shows the eight phase positions; but also two more prominent phases 180° apart. This is due to the STANAG 4285 (this example) structure having an 80 symbol synchronization sequence sent in 2 PSK in each 256 symbol frame.

19.6.5 PSK (3) Example Results

Summarizing:

Modulation:	8-ary PSK
Mode:	Continuous
Sub-carrier tone:	1802Hz
Symbol rate:	2402 sym/sec.
Characteristic:	Regular 80 symbol in 256 symbol frame sent in 2-PSK. This is characteristic of STANAG 4285 waveform.

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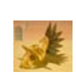
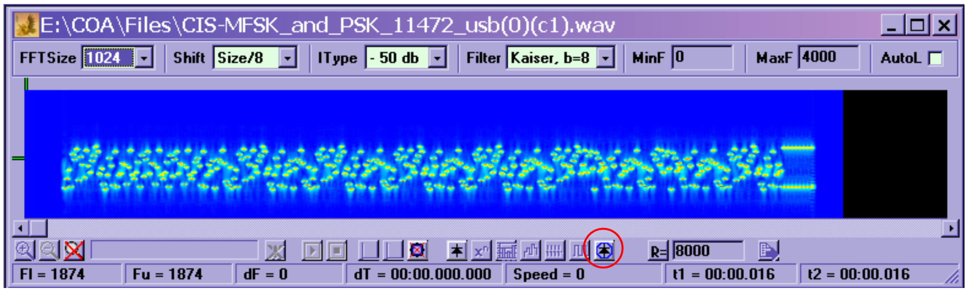


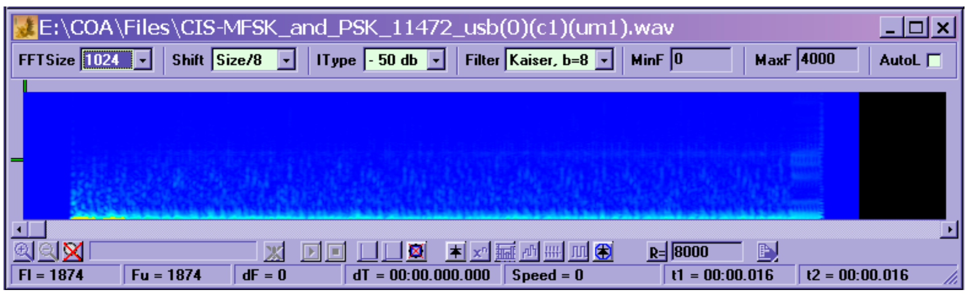
19.7 Analyzing MFSK

MFSK = Multiple Frequency Shift Keying. This system employs a number of tones in a set. Only one tone is transmitted at any instant in time.

19.7.1 Baud rate.

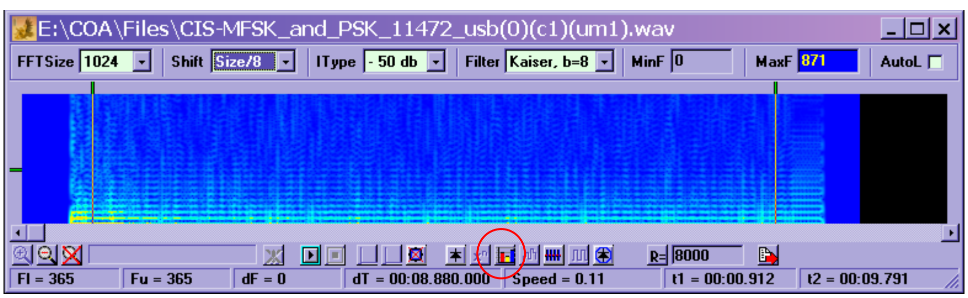


Load and prepare the signal. Call the Modified Quadrature Amplitude Detector.



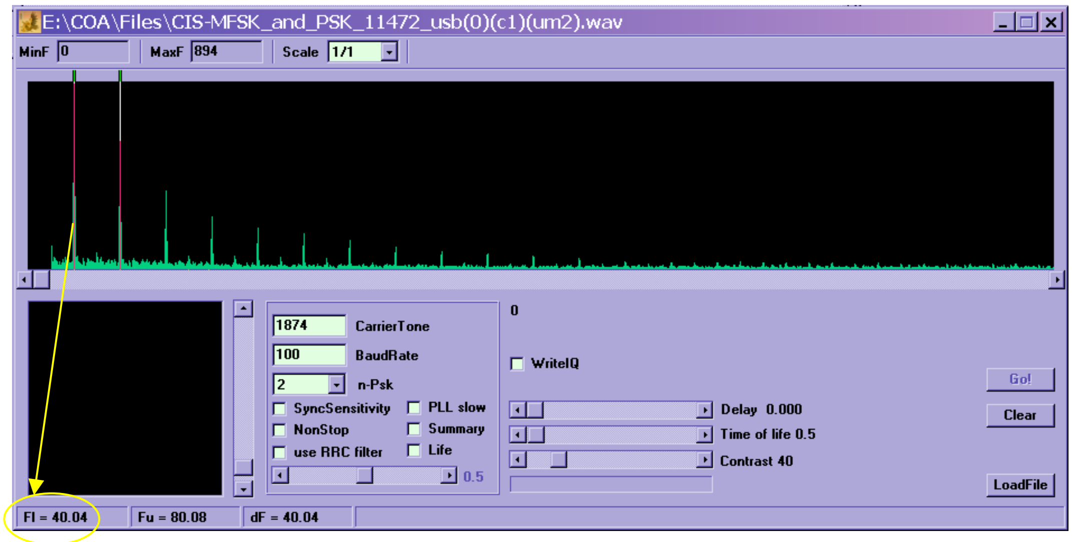
Datum results with baud lines not displayed.

See 19.3.1.1



After Zoom+ adjustment lines visible.

Set time cursors and click High Resolution module button.

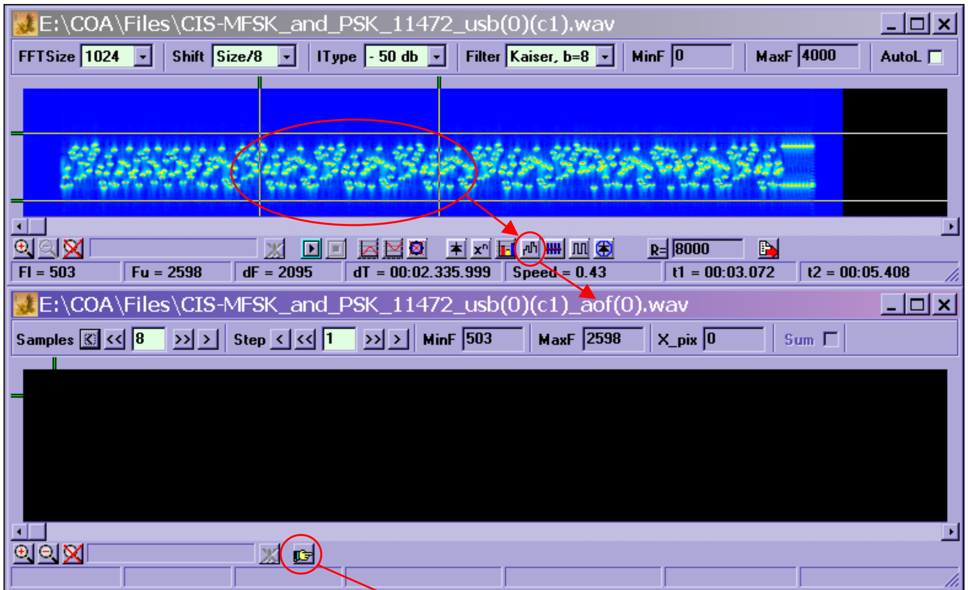


Align the Fl time cursor with the longest spike. The baud rate is 40 Bd.

Unit element time is 1000/40 = 25 mS

The Fu cursor aligned to the next spike indicates first harmonic.

19.7.2 Tone structure.

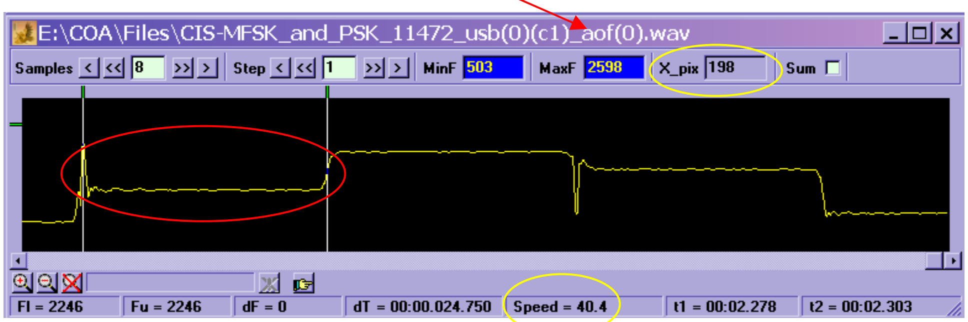


Select a section of the signal.

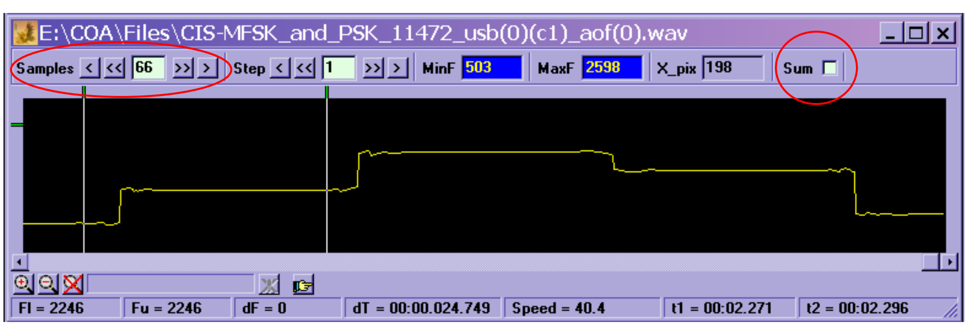
Click the AOF button.

A blank **-aof** window is created.

Click the Make Image button.



At the end of processing align the time markers with one unit period.
Note the value of **X_pix**.
Note also with time markers positioned Speed=40bd.



Enter **X_pix/3** result as Samples parameter and update by clicking the Make Image button.

On completion check Sum

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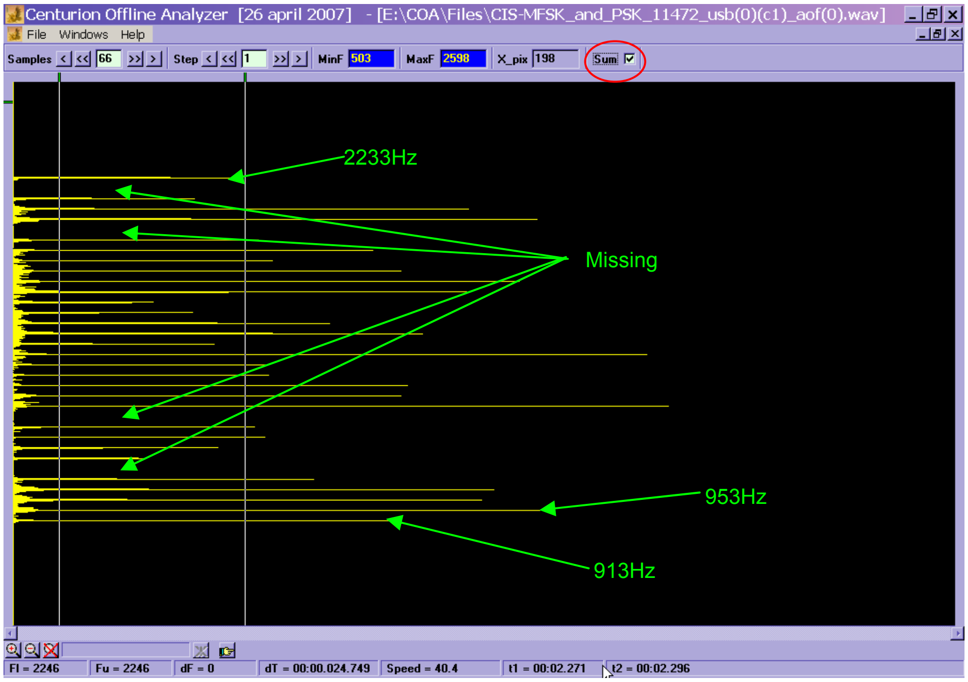
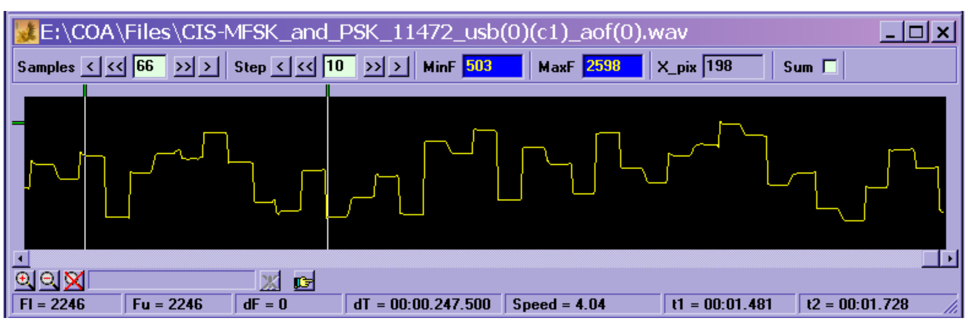


Maximize the window for best presentation. Each line represents a tone in the tone set. The more each tone is called the longer the line. Each may be measured using the horizontal marker.

This shows a system with 34 tones.

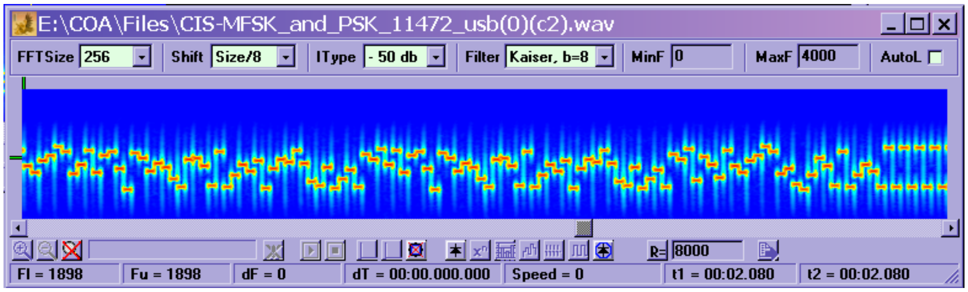
Lowest tone: 913Hz
Second tone: 953Hz
Highest tone: 2233Hz

Four tones are missing. This is due to no activity on these during the selected signal period.



If a **_aof** image is created with a Step of 10 compared to the previous **-aof** image a slower trace is produced. Note the speed is now shown as 1/0th of the previous value.

19.7.3 MFSK Example results.



Number of tones: 34

Highest tone: 2233Hz

Lowest tone: 913Hz

Tone separation: 40Hz

System bandwidth: 1320Hz

System center: 1573Hz

Baud rate: 40bd

Bit unit period: 25mS

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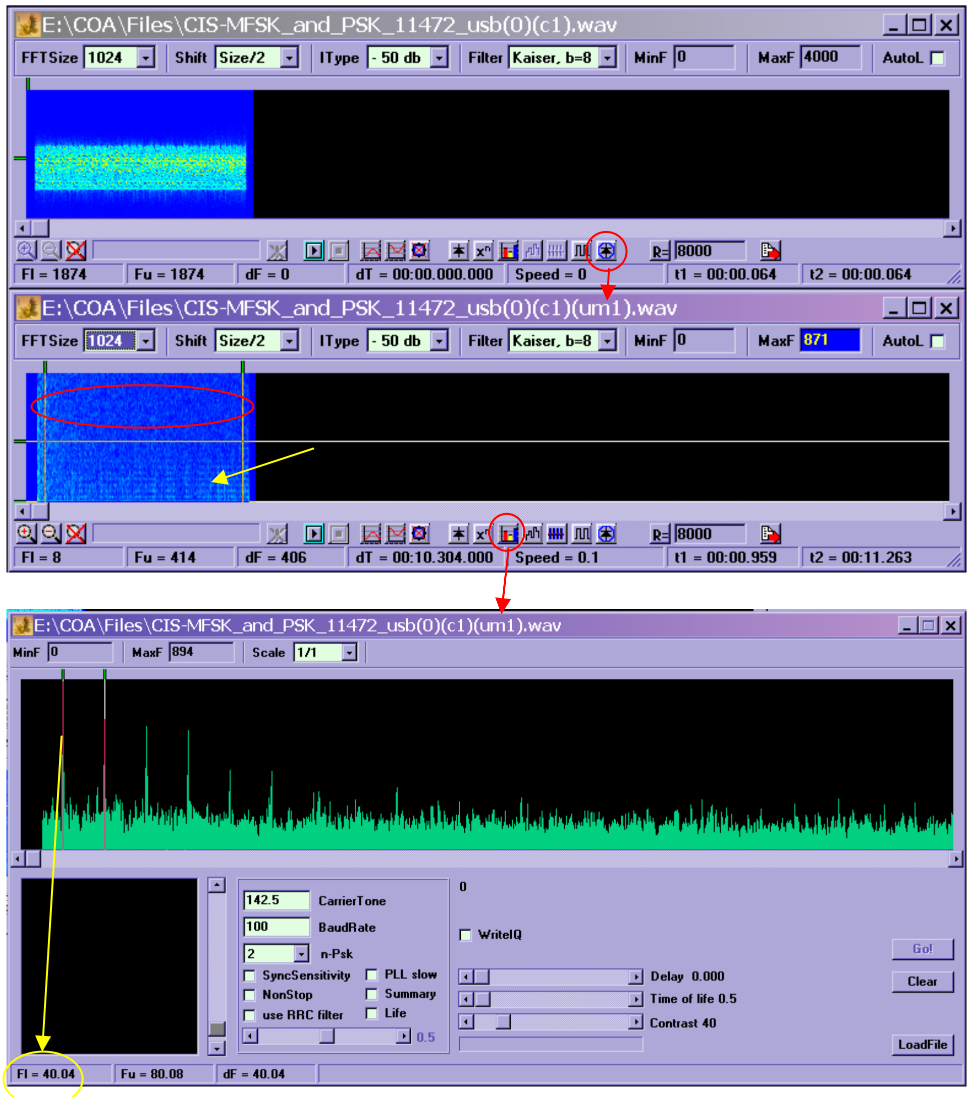
19.8 Analyzing OFDM

19.8.1 Symbol rate.



Load the signal and prepare.

Call the Modified Quad Amp Det module.

Adjust signal to display baud line and harmonics per 19.3.1.1

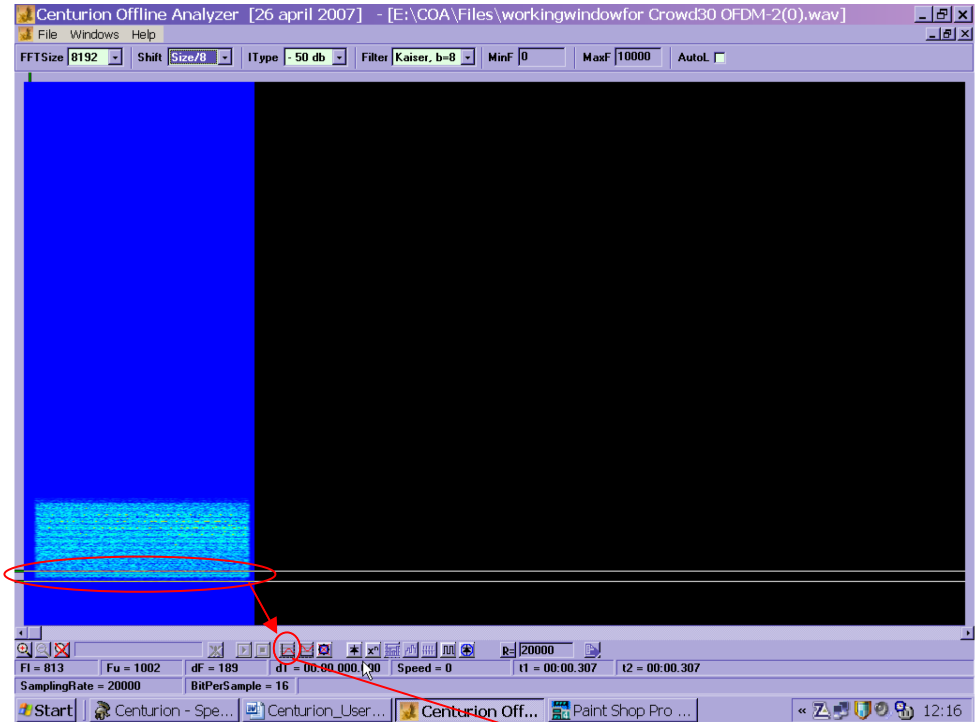
Set time markers. Call High Resolution module.

Align the FI vertical cursor with the longest spike to measure the rate.

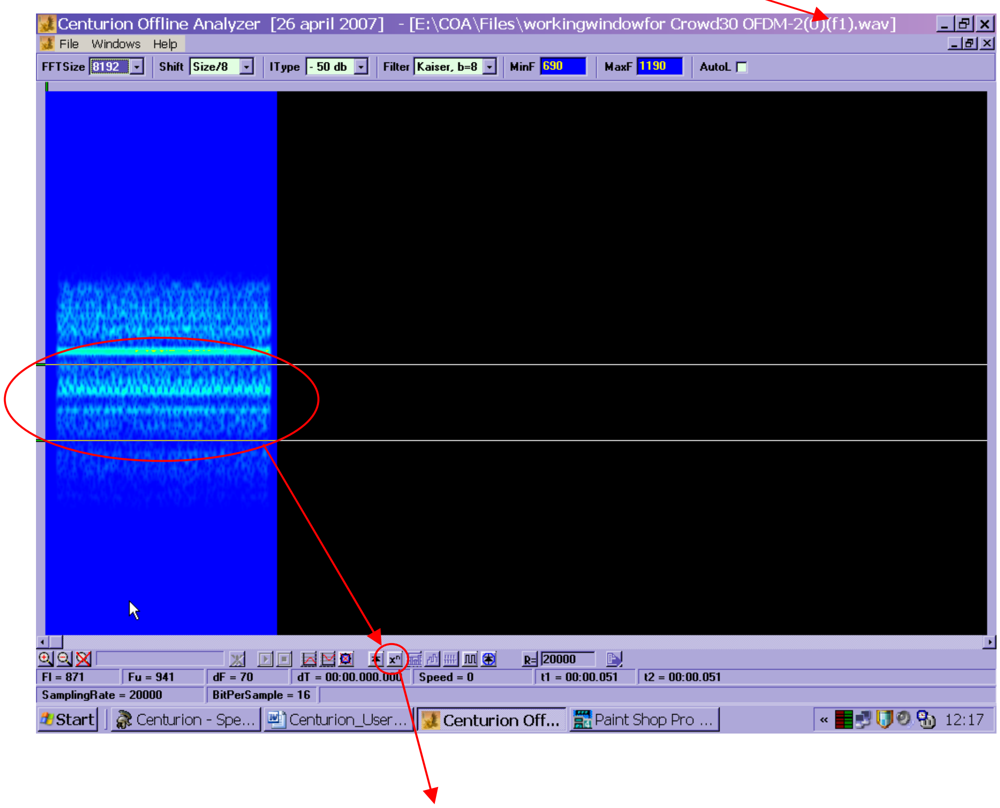
In this example 40 bd is the baud rate.

Use the Fu marker to measure the harmonics.

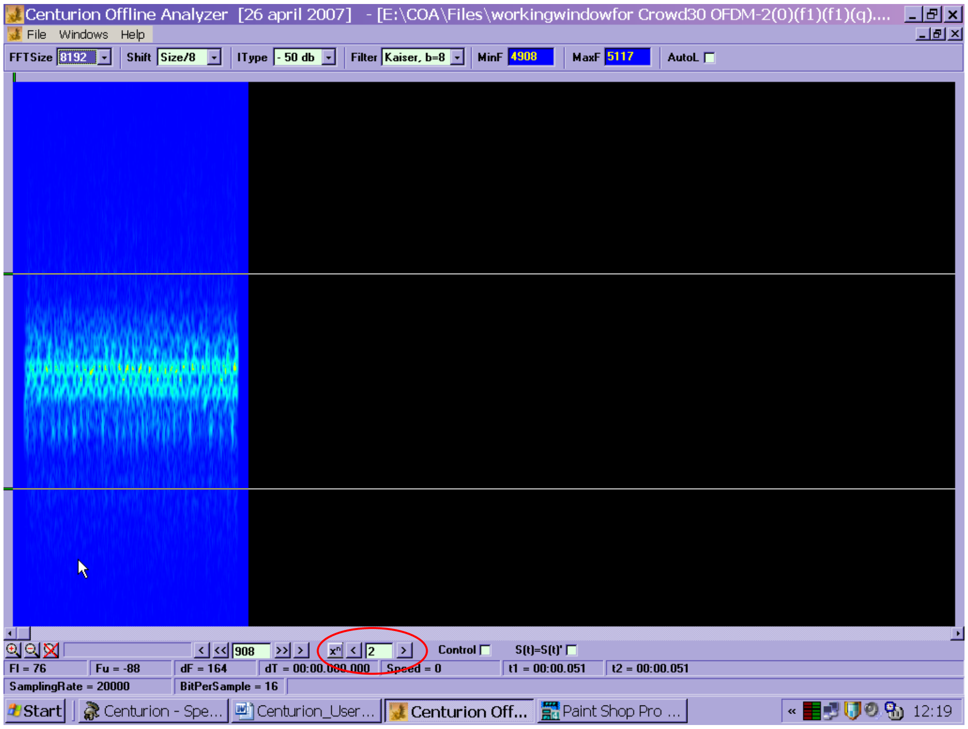
19.8.2 Determining channel frequency and modulation.



Delineate the lower end of the channels and filter.

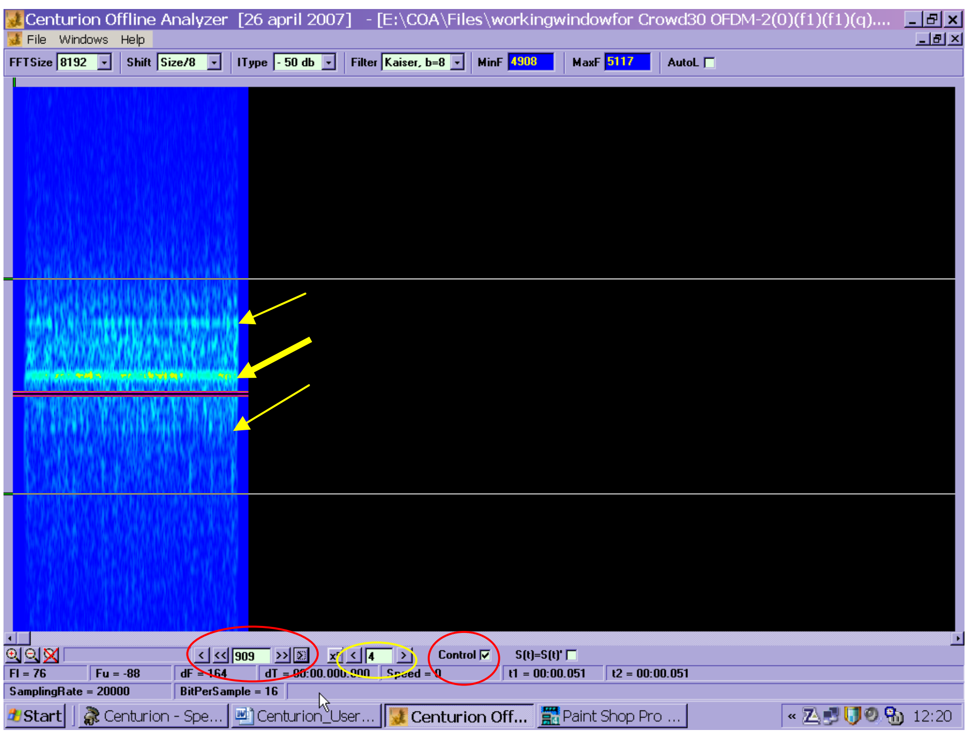


Zoom and further filter the lowest channel.
Note this system has a pilot tone (952 Hz) adjacent.
Delineate channel and call Involutions module (**X**^{n})



In this **q** window delineate and test for n-ary using 2, 4 and 8 variants looking for the symbol rate line, and it's two adjacents.

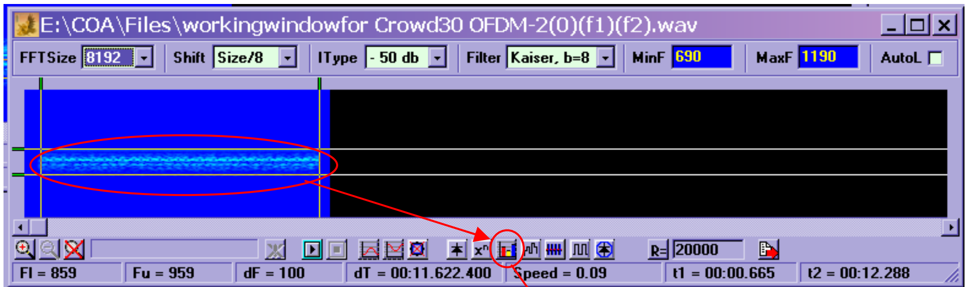
After each change click the $\mathbf{X^n}$ button to process.



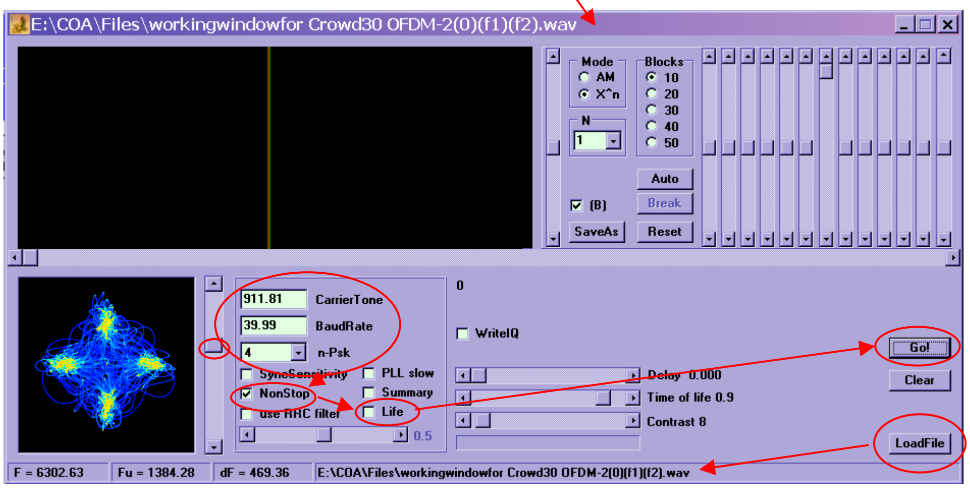
This occurs in this example with 4-ary

Check Control and adjust the frequency until the (red) control line is aligned with the central symbol rate line. In this case shown offset but 912 Hz is the correct value.

19.8.3 Displaying constellation



Return to the parent window and delineate the channel.
Call the Phase Viewer.



Click LoadFile and select the source file from the list.

Set (as integers) the measured values into Carrier tone, Symbol rate and n-PSK.

Check NonStop, Life.

Click Go!

At first the constellation will be very small. Increase the position of the Phase Scale (vertical) slider to achieve a suitable diameter(amplitude).

The Carrier Tone and Symbol Rate will alter to the correct values.

The constellation is in real-time and may produce a disjointed display. Try Un-checking Life, and reducing the Contrast. The constellation will build over time. Click Break when a suitable display is achieved.

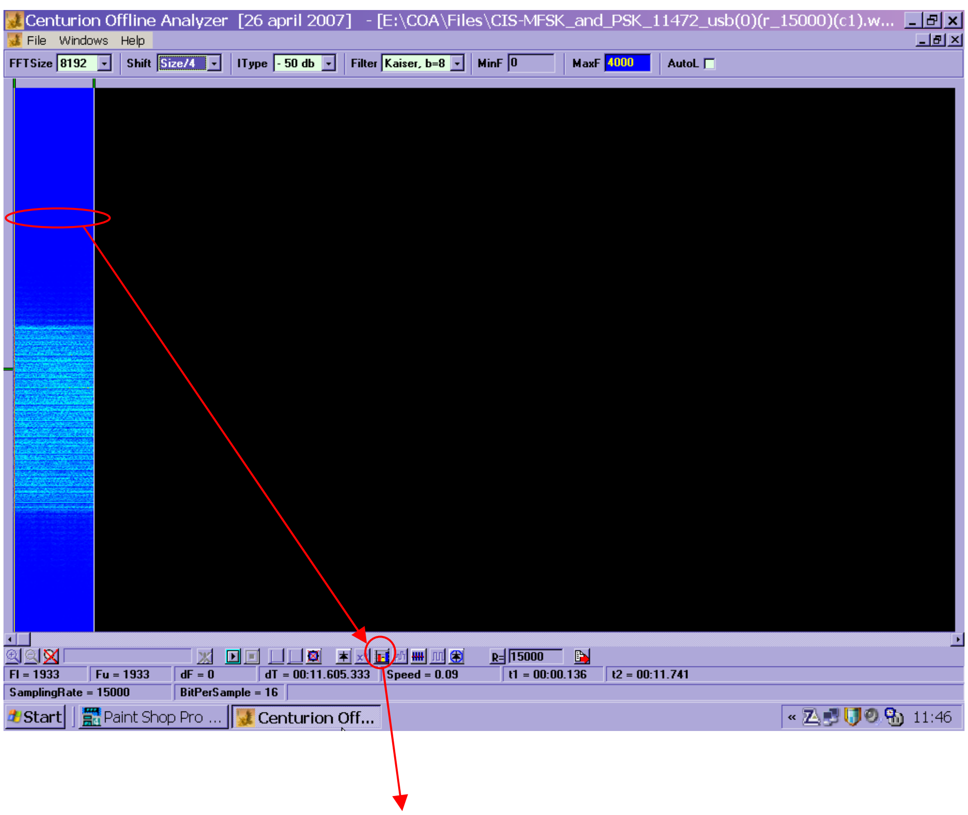
19.8.4 Tone/channel structure.

This example is difficult to assess due to the number of, and close proximity to, adjacent channels which cannot readily be counted as per (say) Section 19.8.2. Increasing the sampling rate from 8000 to 15000, and FFT Size from 1024 to 8192 makes little improvement.

Being orthogonal, and with a symbol rate of 40 symbols/sec, it is worth assuming as a start point that the channel separation is 40Hz and working on that as a hypothesis.

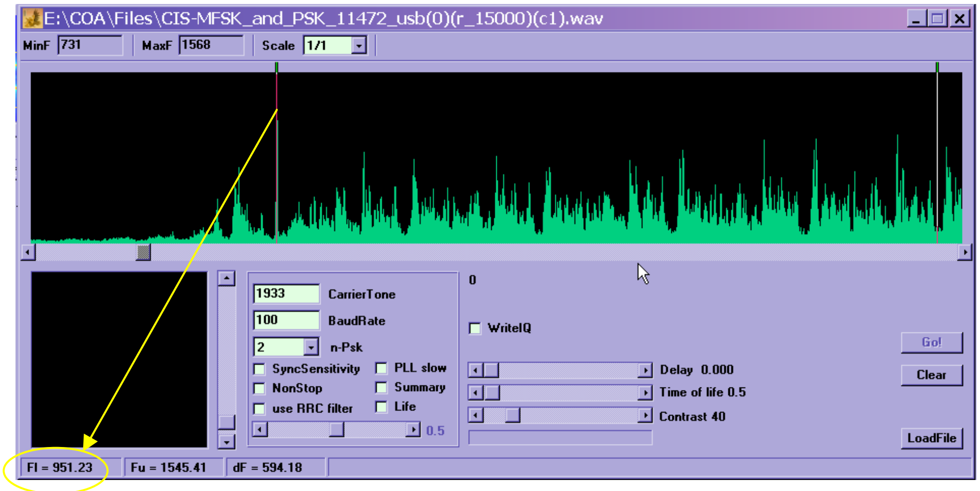
The lowest channel is 912 Hz. The next step would be to measure channel two. In this case it is an unmodulated tone.

Isolate the channels for analysis.



Maximize the window for improved clarity.

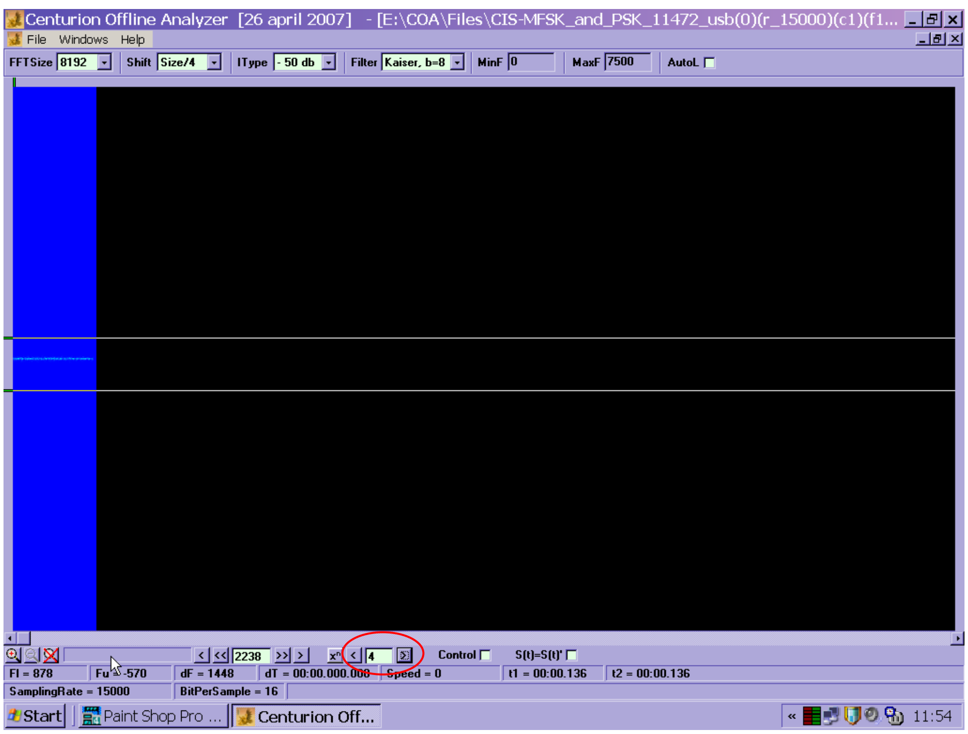
Delineate and call the High Resolution module.



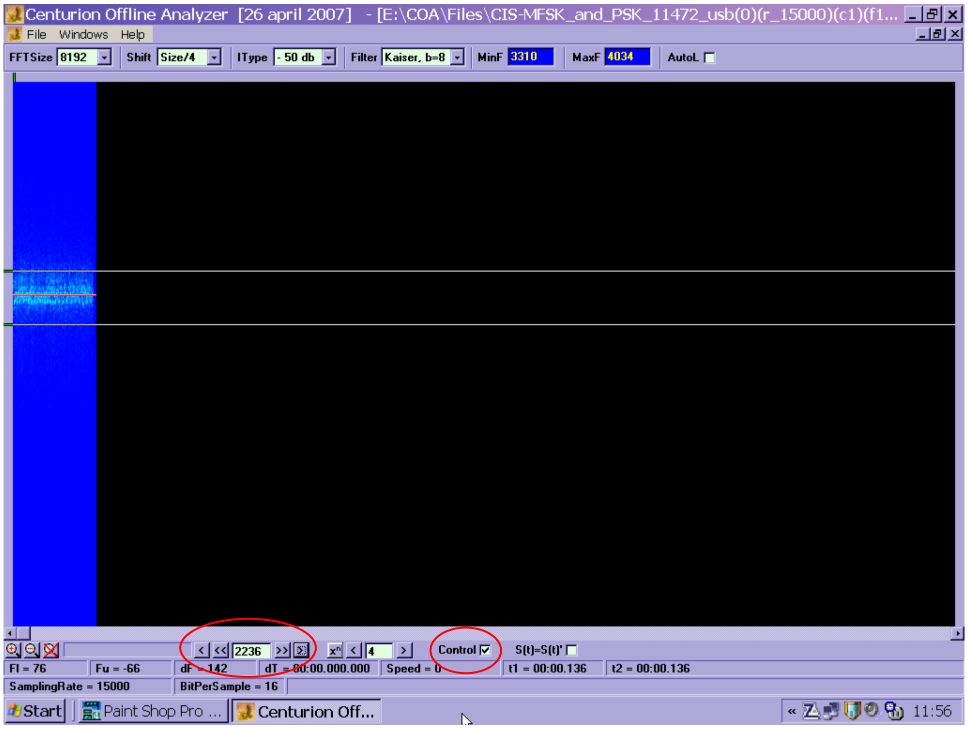
Align the FI marker with the large unmodulated tone.

The pilot measures 951Hz confirming the presumed channel separation of 40 Hz (951-912=39Hz).

The next step is to measure the upper channel. Using previous procedure (Section 19.8.2) isolate (filter) the top channel area, delineate and call the Involutions module **Xⁿ.**

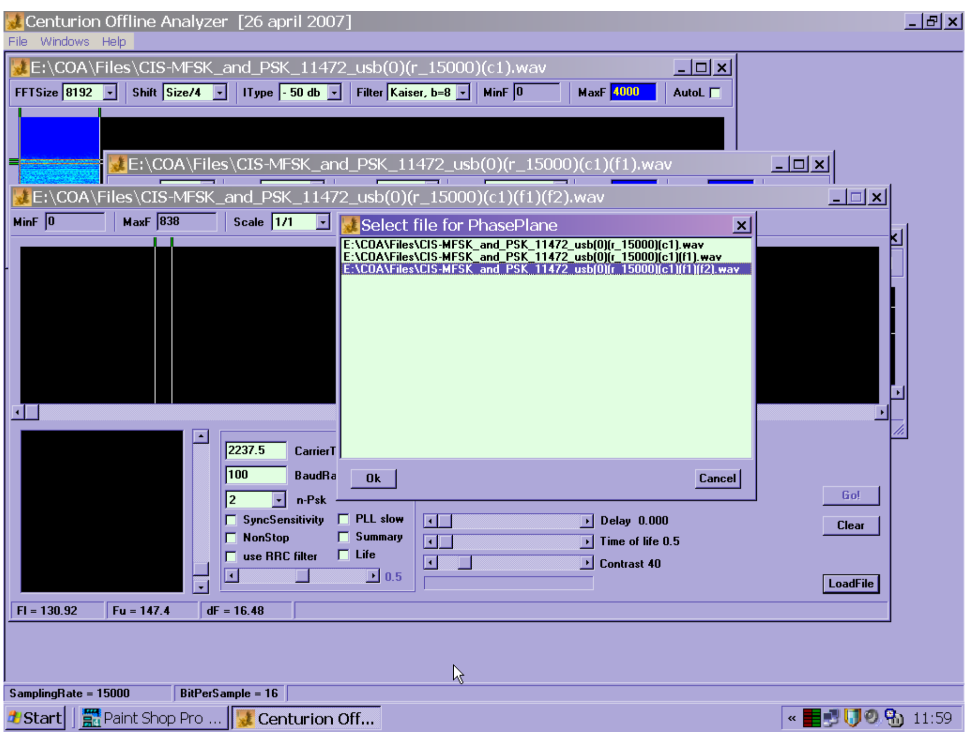


Set n-ary to 4 as this has already been ascertained.



Check Control and adjust frequency to center, calling Involutions module **X^n** after each change to update.

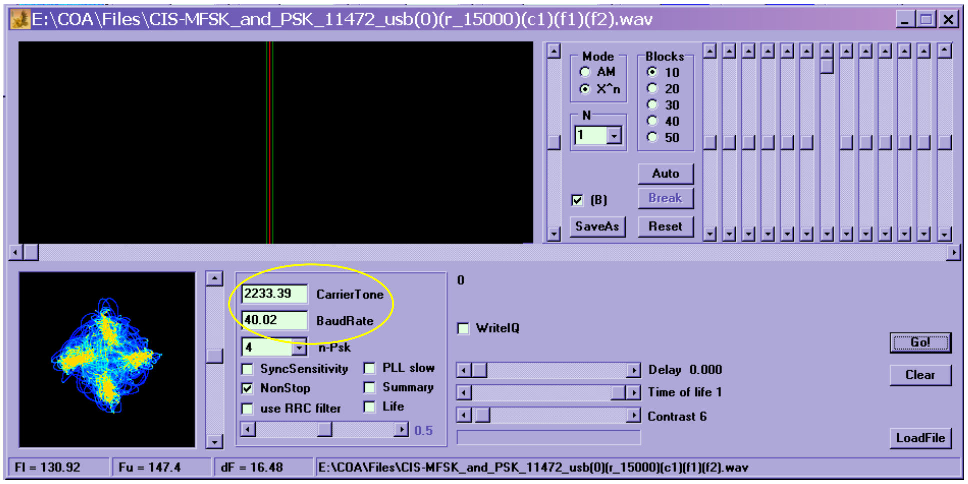
Return to the source window, delineate and call the Phase Viewer.



In the Phase Viewer click LoadFile, select the file and click OK.

Set (integers) Carrier Tone, Symbol Rate and n-PSK to values measured.

Check Non-stop and Go!.



The Carrier Tone settles on 2233 Hz. This is the top channel frequency.

From this it can be established that the number of channels is

[Top channel - Lowest Channel/40 Hz] + 1

= (2233 - 912 / 40) + 1

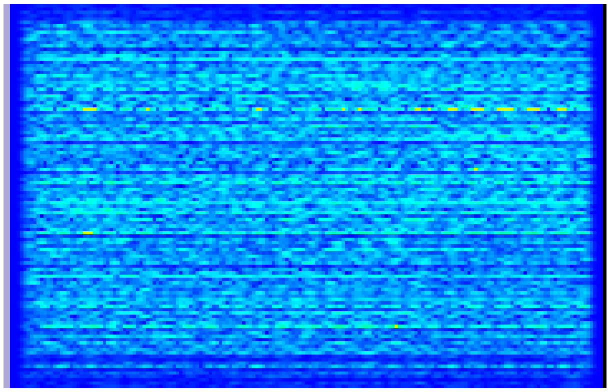
= (1321 /40) +1

= 33 + 1

= 34.

Also the signal bandwidth (Top-Lowest channel) = 1321 Hz.

19.8.5 OFDM Example results.



Channels	34
Pilot tone	952 Hz
Low channel	912 Hz
High channel	2233 Hz
Modulation	4-PSK
Symbol rate	40 symbols/sec
Signal bandwidth	1321 Hz

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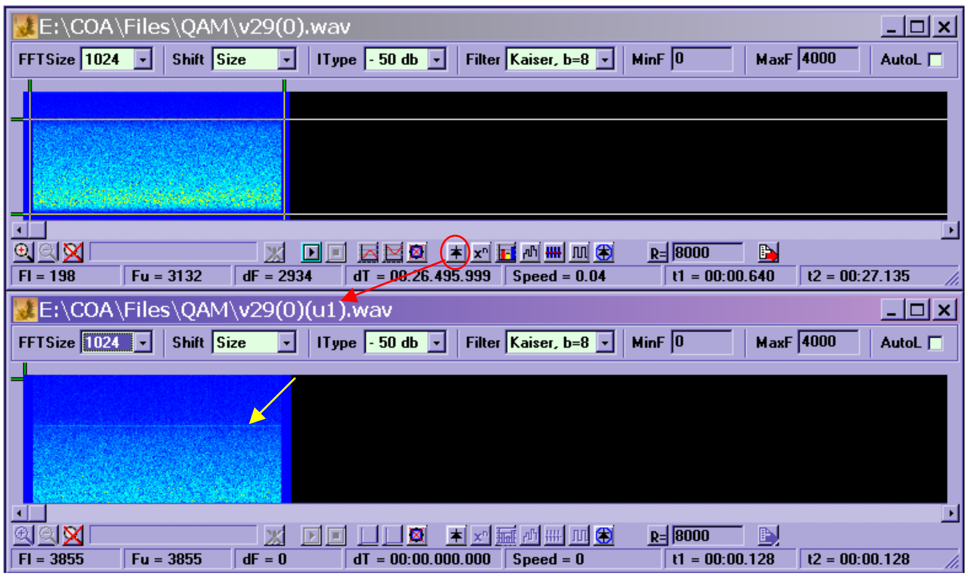
19.9 Analyzing QAM

19.9.1 V29

An easy example to start. This is not pure QAM (Quadrature Amplitude Modulation) but the principles used for the analysis of this signal is also used for QAM.

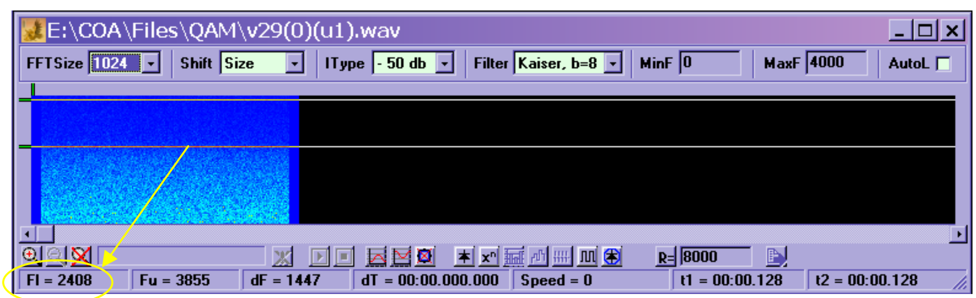
19.9.1.1 Determining symbol rate



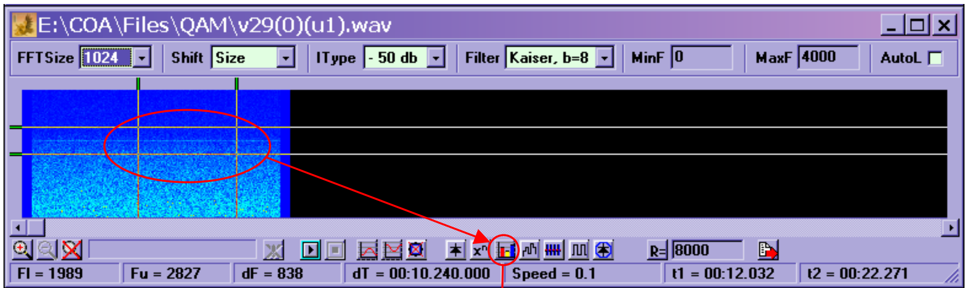
Prepare the signal. Open file and delineate.

Call Quad Amp Det module

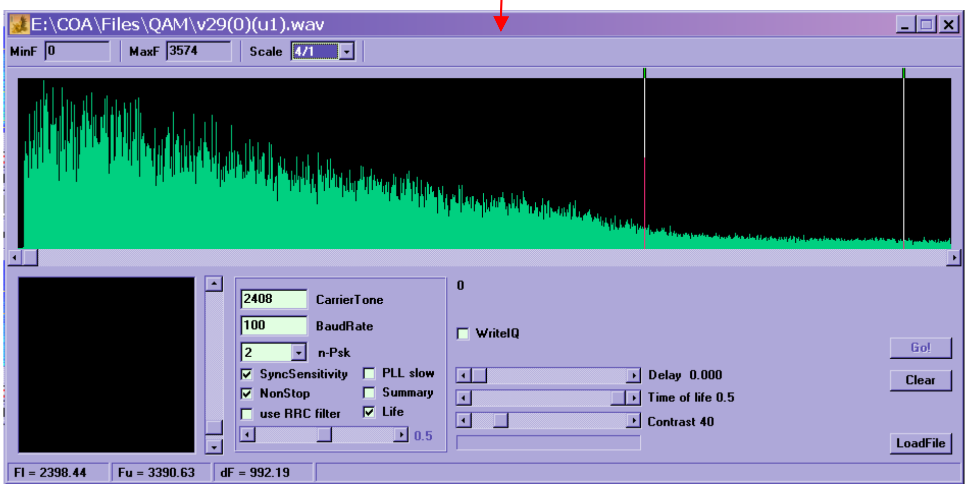
In the **u** window the symbol rate line is visible.



The FI horizontal marker may be aligned and measured from the status line.
Symbol rate 2408.



Alternatively the signal in the **u** window can be delineated and the Viewer called.

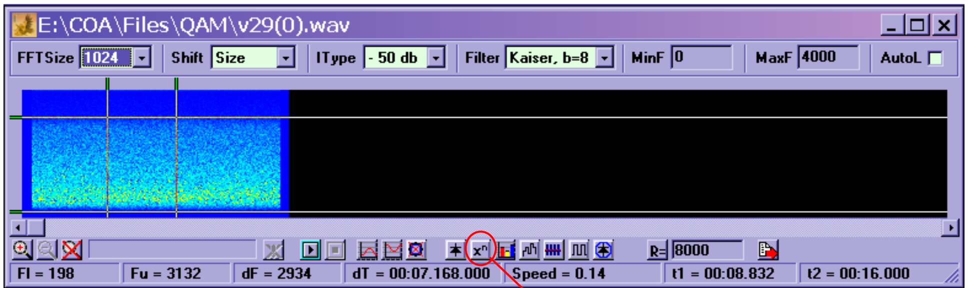


Scale is adjusted to reveal the spike and the Fl marker aligned.

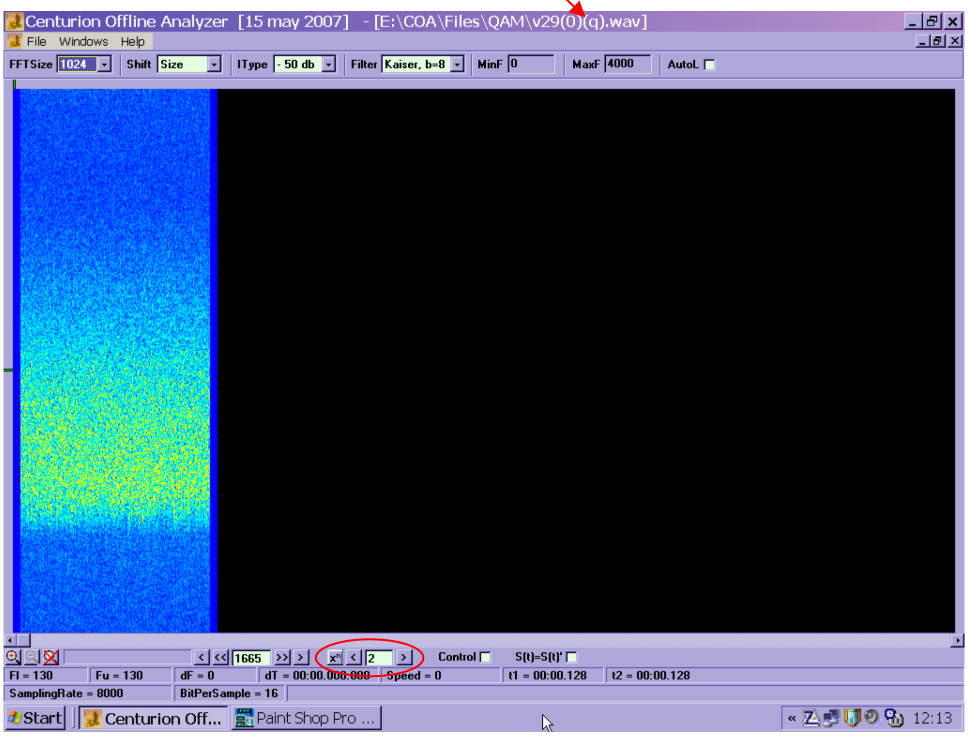
The symbol rate is given as 2398.44.

The two methods point to a symbol rate of 2400 symbols/sec.

19.9.1.2 Determining carrier and initial n-ary

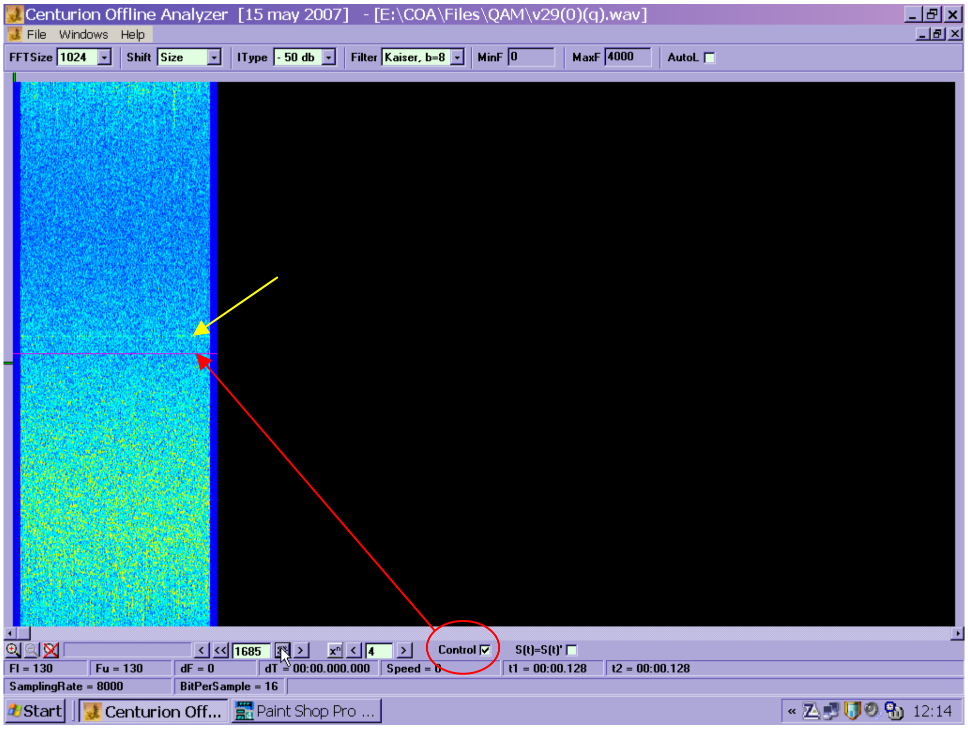


Return to the source window, delineate and call the X^n function.



The **q** window shows no information.

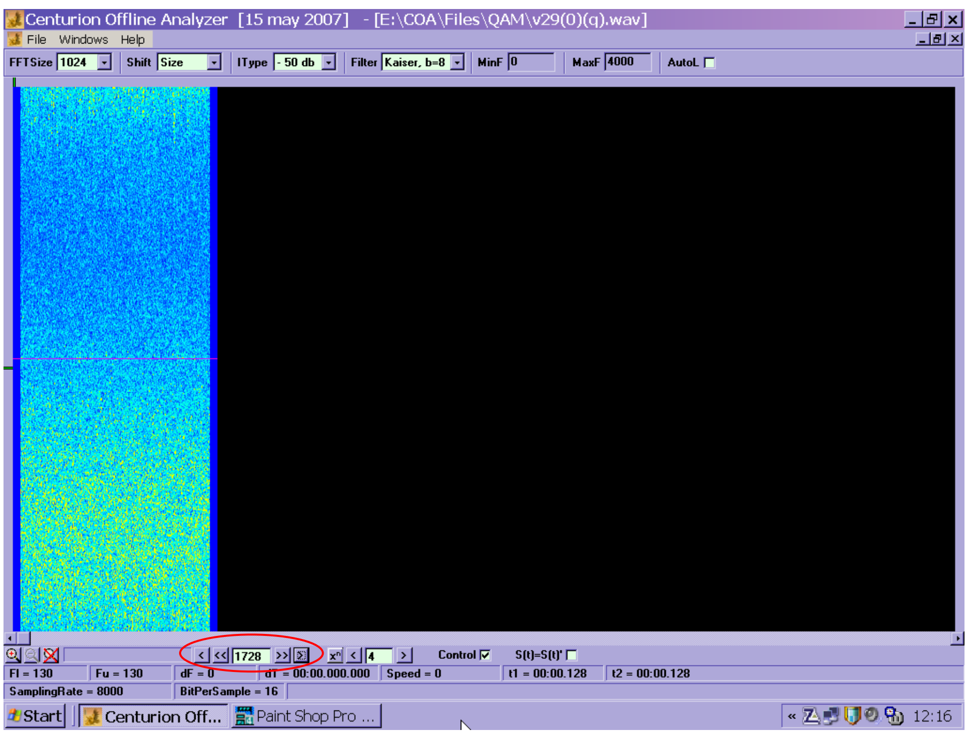
Increase n to 4 and call the X^n function again.



The window now shows a trace line.

Initial n-ary is 4.

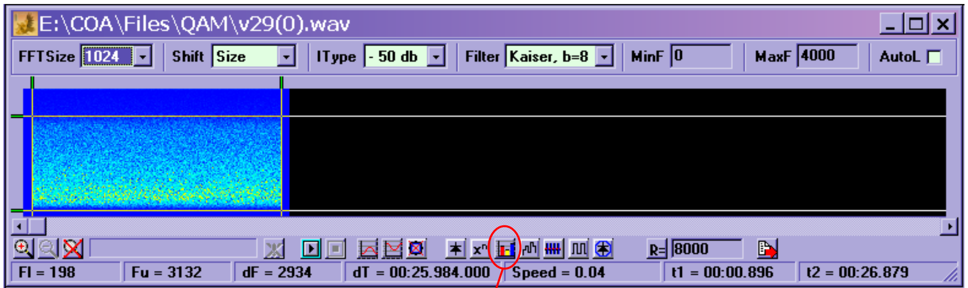
Check the Control box to enable the control line.



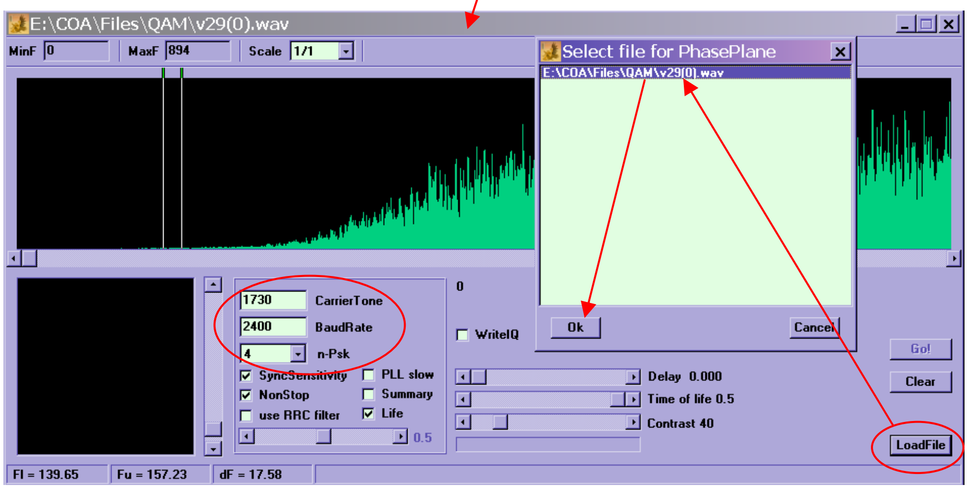
Adjust the frequency counter (followed each time by clicking the **X^n button)** until the two lines are aligned.

The subcarrier is shown to be on 1728Hz.

19.9.1.3 Determining N-ary

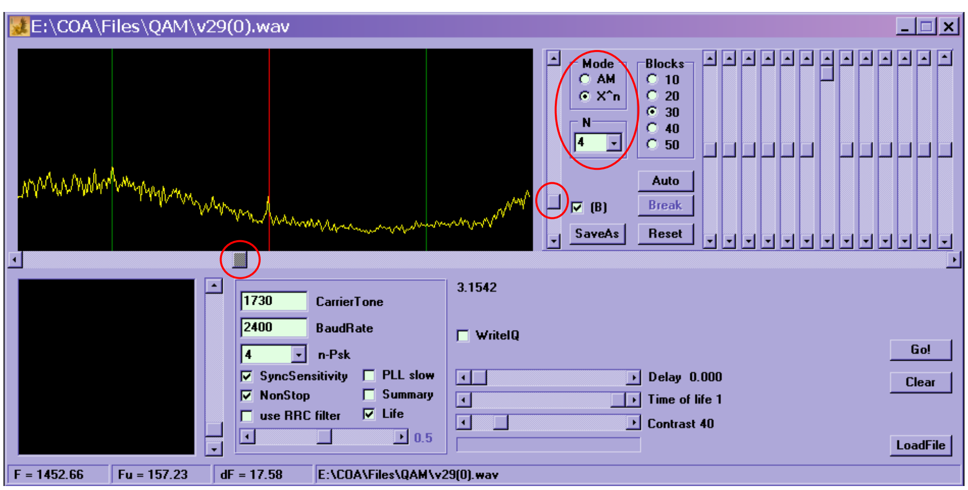


Return to the source window, delineate and call the Phase Viewer.



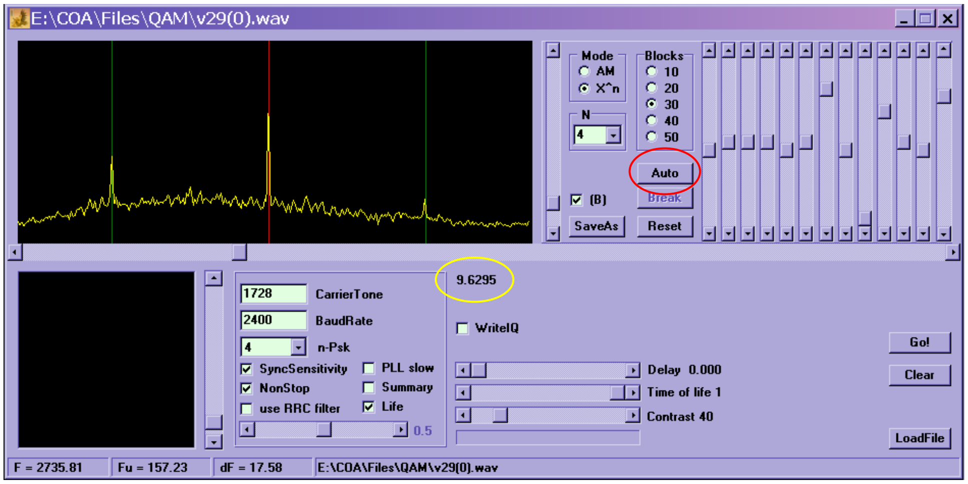
Enter parameters already determined: CarrierTone 1728Hz. Baud(Symbol)Rate 2400. n-Psk 4

Select LoadFile

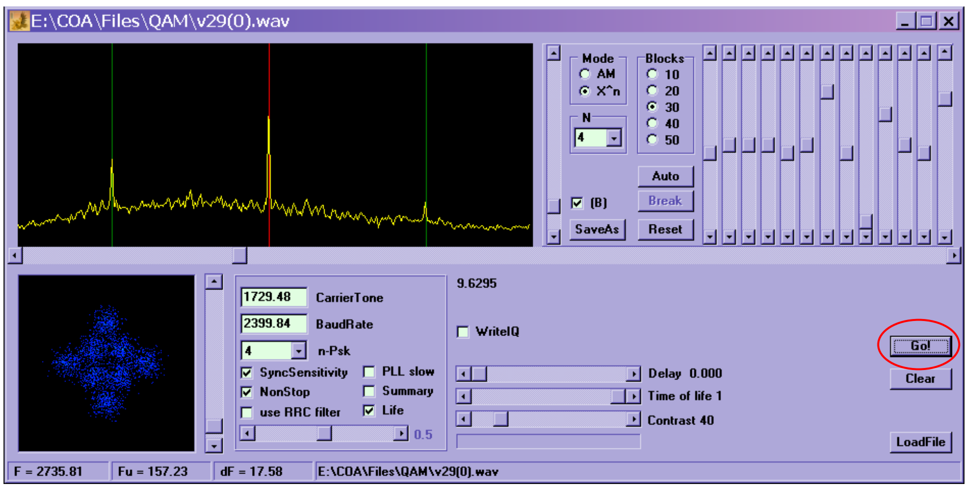


Set Mode = **X^n**
N=4

Adjust sliders: Horizontal for max amplitude, and vertical for approximately midway.



Execute AUTO a number of times until value stops rising.

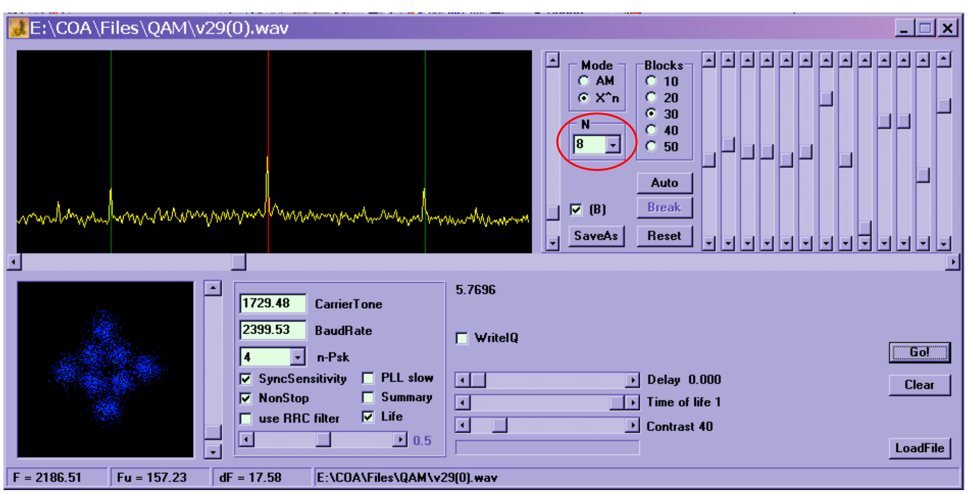


Click Go! button to display constellation.

Note 8 symbol points.

CarrierTone and Baud(Symbol)Rate settle on actual values. 1730Hz and 2400 symbols/sec.

This is not classical QAM but close. However it is also not classical PSK-8. Therefore AM Mode is not used in the ISD corrector - only X^n Mode.

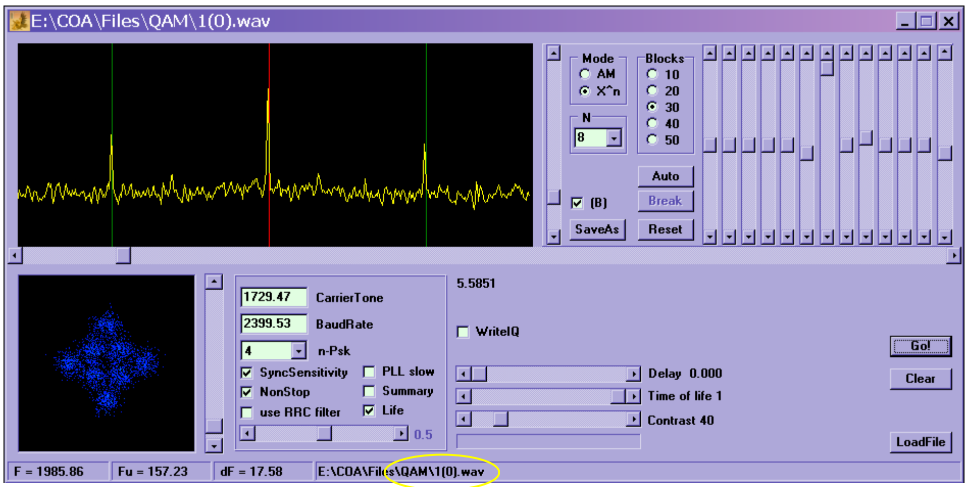


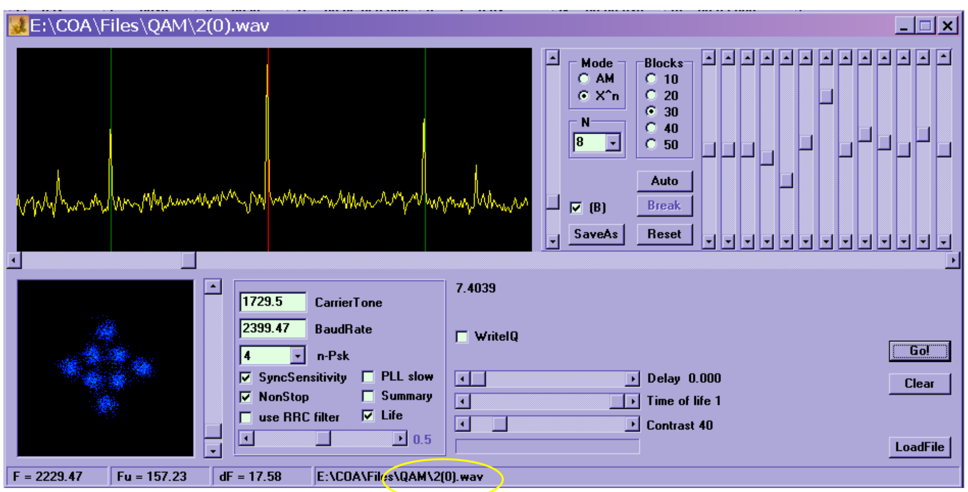
Change N=8. Continue AUTO processing until value stops rising. Click Go! button and check constellation. Note - Always check constellation before actioning Save As. Save As (eg) 1.wav in spite of fact of poor quality.

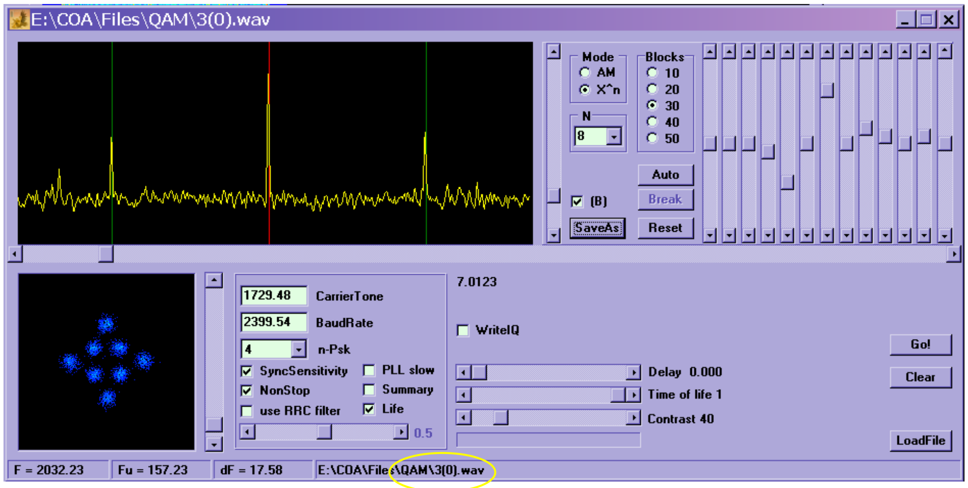
###

1 Close the current source window. Do NOT close the Viewer.
2 Open the previously saved file (File|OpenAudioFile).
3 Action LoadFile.
4 Execute AUTO processing a number of times.
5 Click Go! and check constellation.
6 Save As (eg 2.wav ie next increment).
7 Return to ### above and repeat.

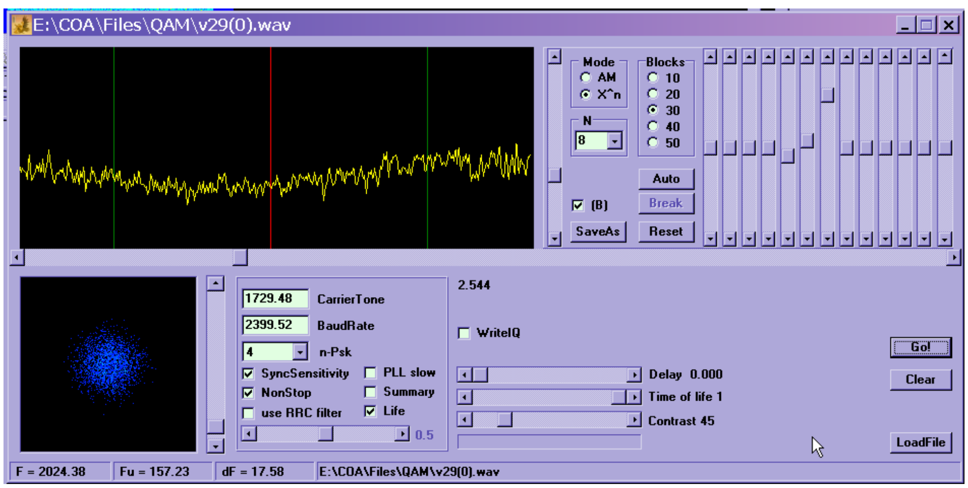
The following images show the results after each loop. Note the improvement in the constellation clarity.







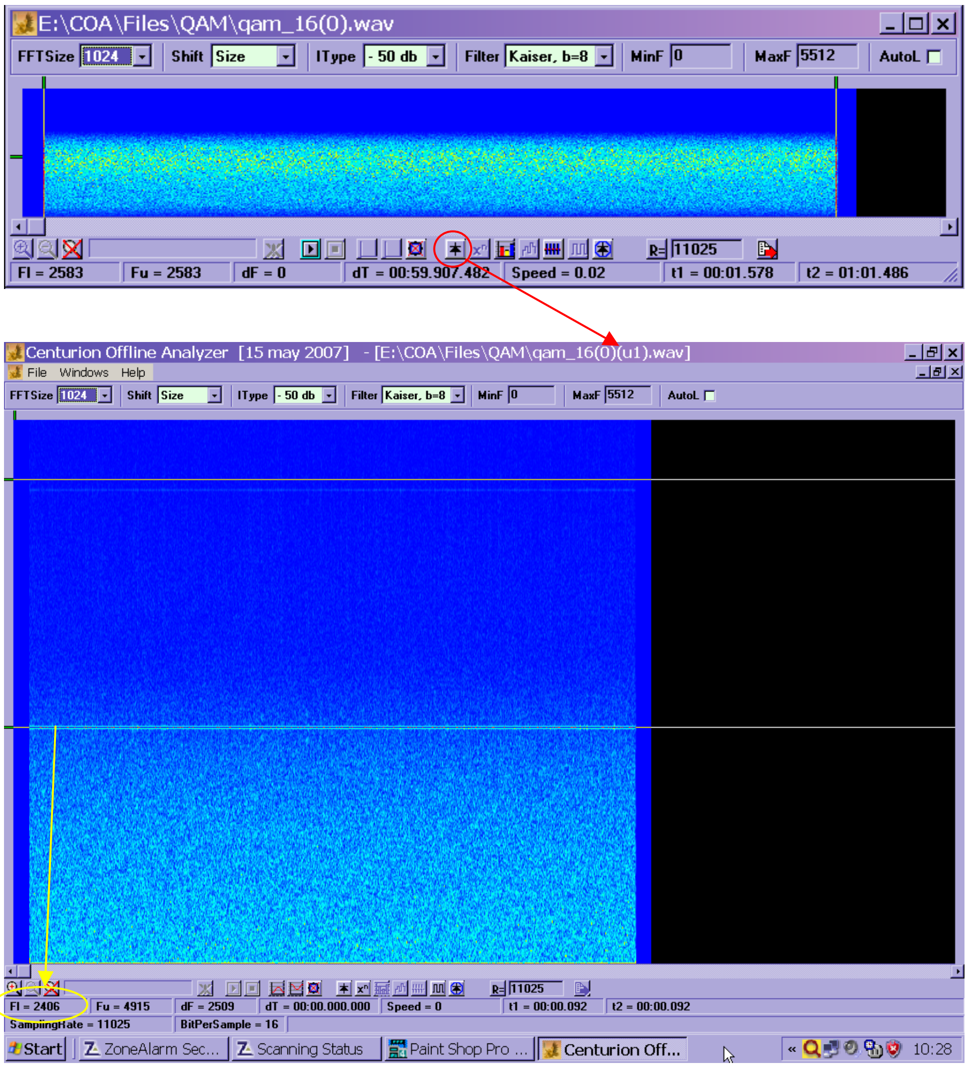
The following image is based on the original V29.wav file (ie no correction). Compare this with that above based on 3.wav plus unsaved correction.



19.9.2 QAM-16

This is a classic QAM signal.

19.9.2.1 Determining symbol rate.



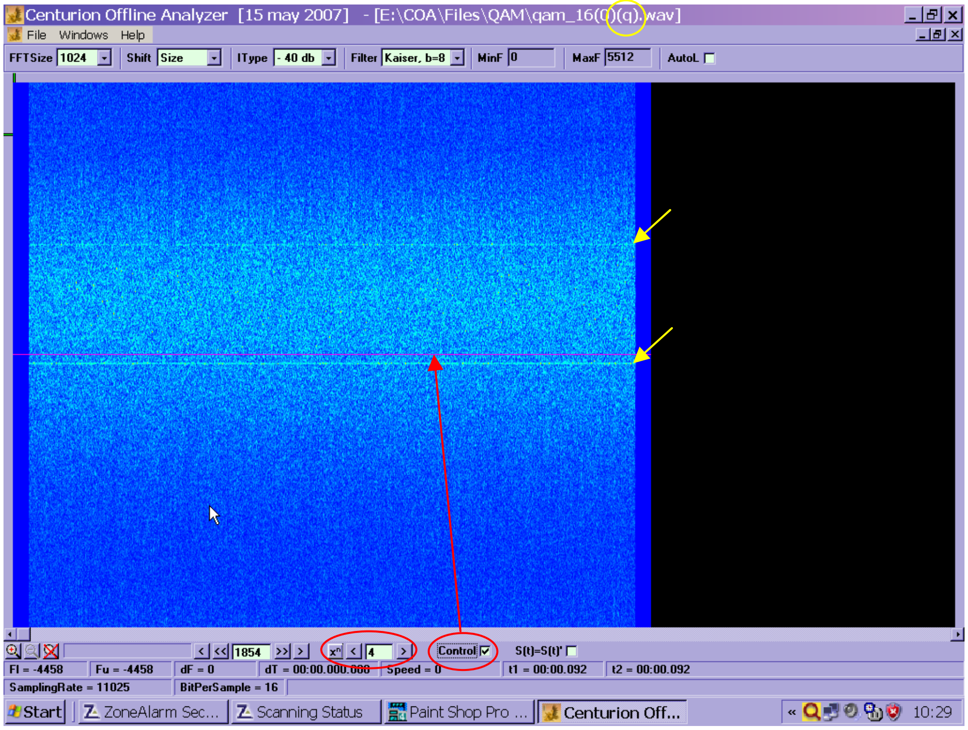
Prepare and delineate the source file.

Call the Quad Amp Det function.

In the resultant **u** window use the horizontal cursor to determine the Symbol Rate.

Symbol Rate is nominally 2406 symbols/sec..

19.9.2.2 Determining carrier and initial n-ary

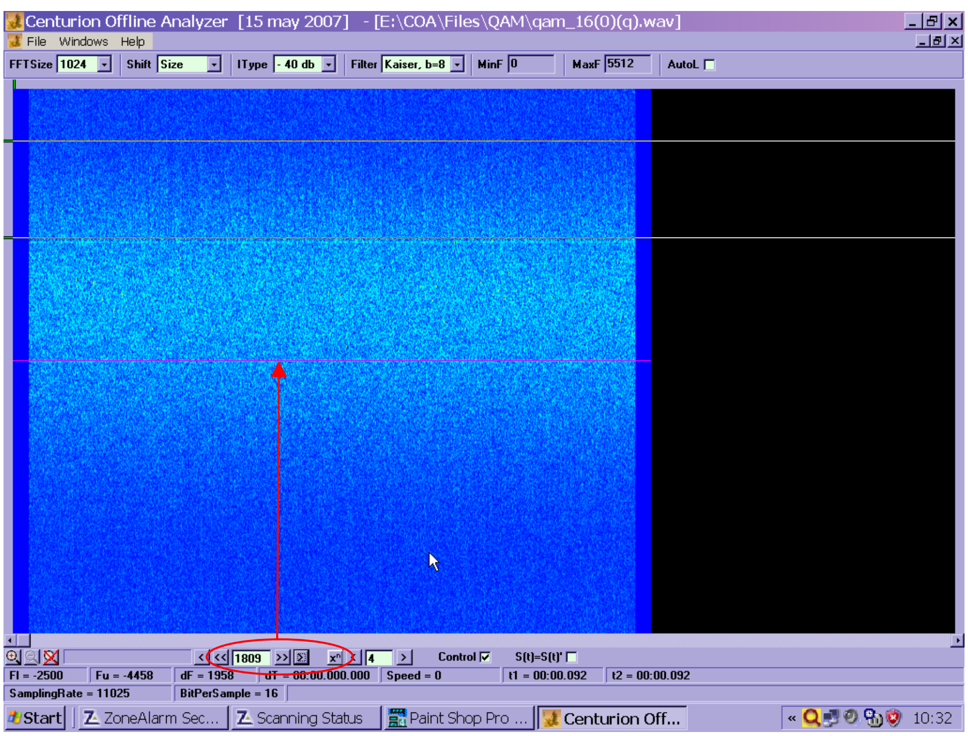


Return to source file, delineate and call X^n function.

In the resultant **q** window increase the n-ary count to 4. Call X^n function again.

Two lines appear. The lower is the carrier. The upper (fainter) line is apparently a symbolrate ghost.

Check Control to enable the cursor for carrier measurement.



One of the horizontal cursors indicates the fainter line is 2400.

Adjust the Control line counter (each time followed by clicking X^n to update) until the two line coincide.

Carrier frequency is nominally 1809Hz.

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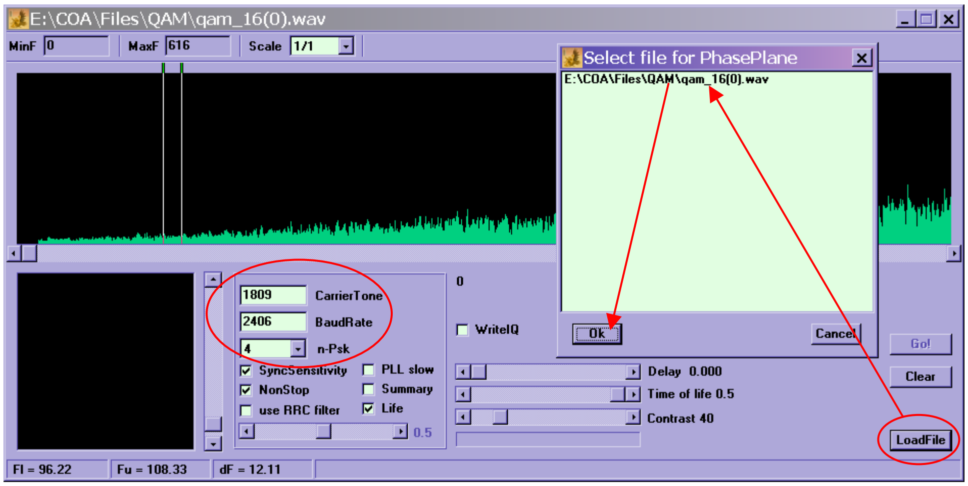
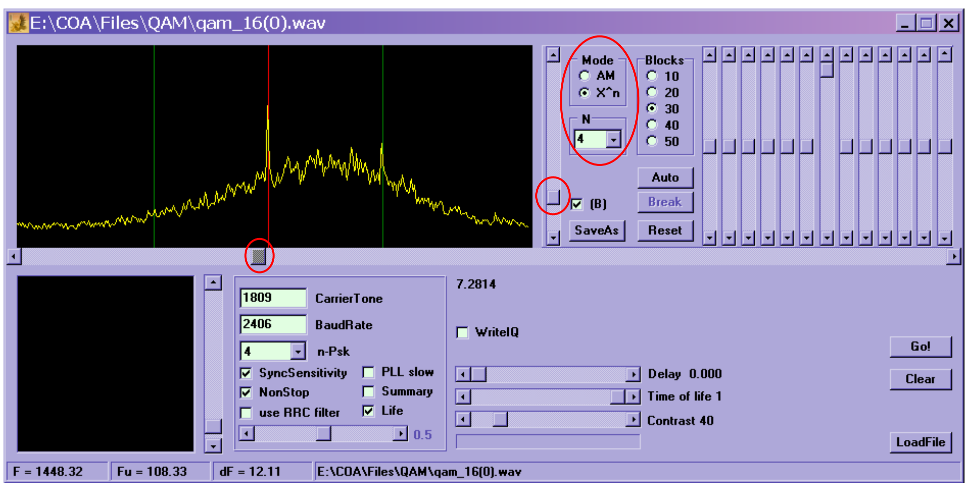
19.9.2.3 Determining N-ary



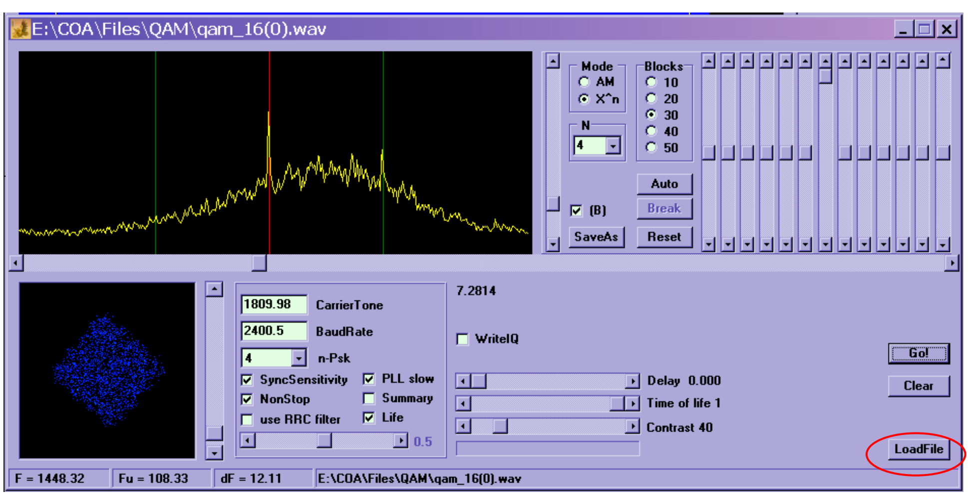
Return to the source file, delineate and call the Phase Viewer.

Enter the previously determined parameters
Carrier 1809 Hz
Baud(Symbol)Rate 2406.
n-Psk = 4.
Action LoadFile.



With the ISD corrector panel visible set
Mode = **X^n** and
N = 4.

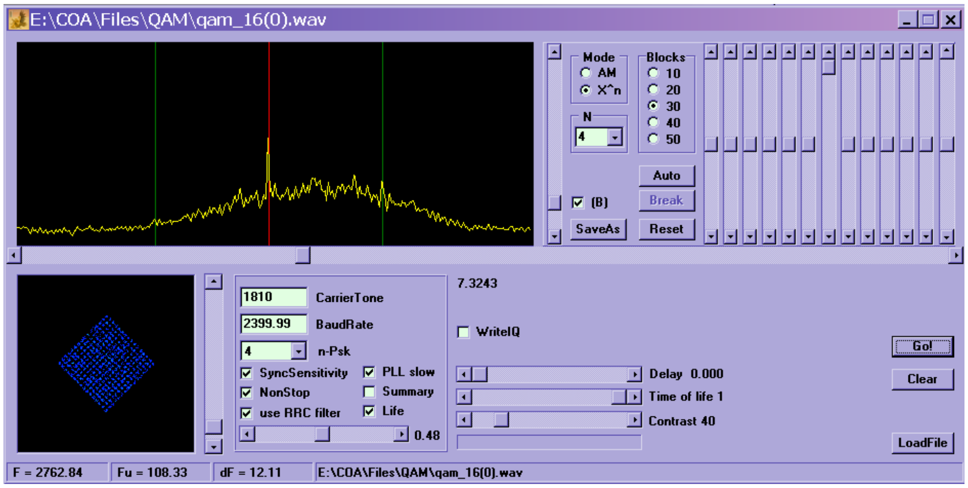
Adjust sliders.



Display constellation by clicking Go! button.

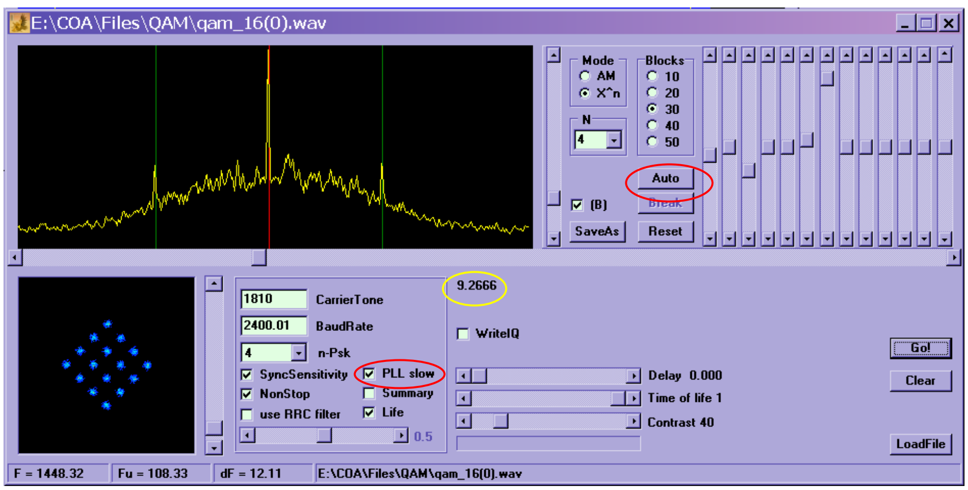
Quality is poor with no ISD correction computed.

Carrier Tone and Baud(Symbol)Rate settle on correct values.



Continuing from the previous image if the Use RRC Filter box is checked a 256 point constellation will appear.

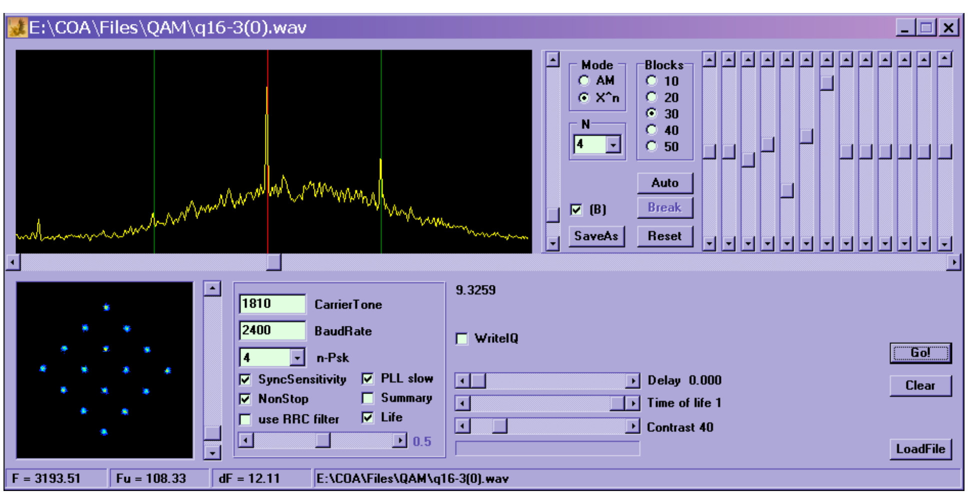
This is a phantom image. This option should only be set for QAM >32-64 and not for this QAM-16.



Process AUTO a number of times and retry Go!.

The display quality becomes meaningful.

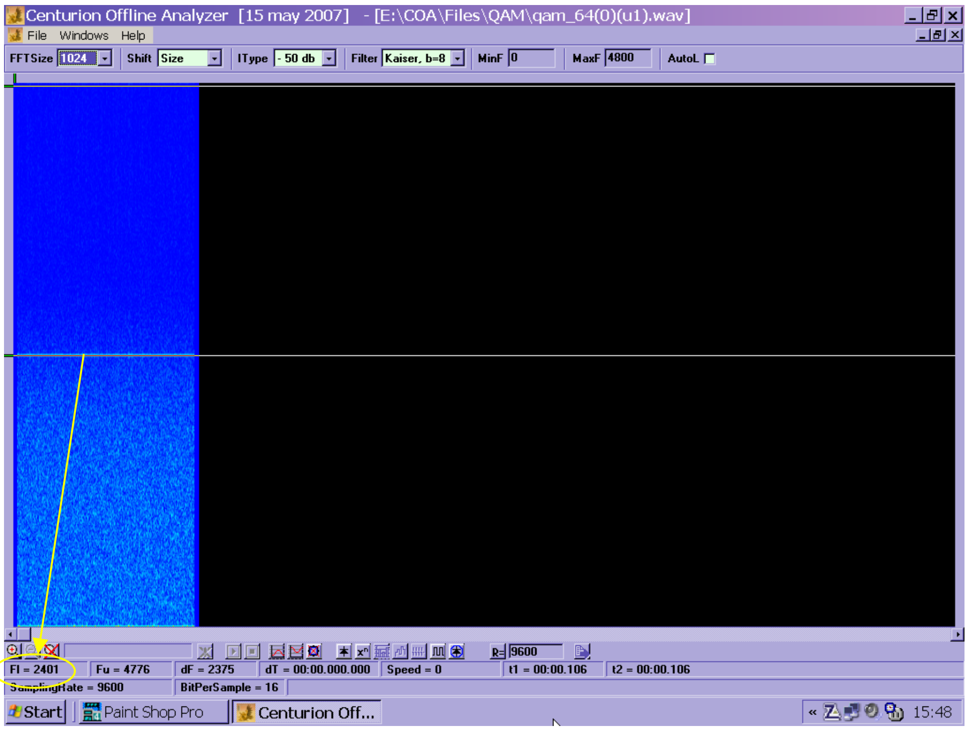
Note: Check PLL slow after each Go! run started and signal synchronized.



If the previous ISD correction is saved and the user repeats this process a number of times as described in Section 19.5.5 the quality of the constellation will further improve.

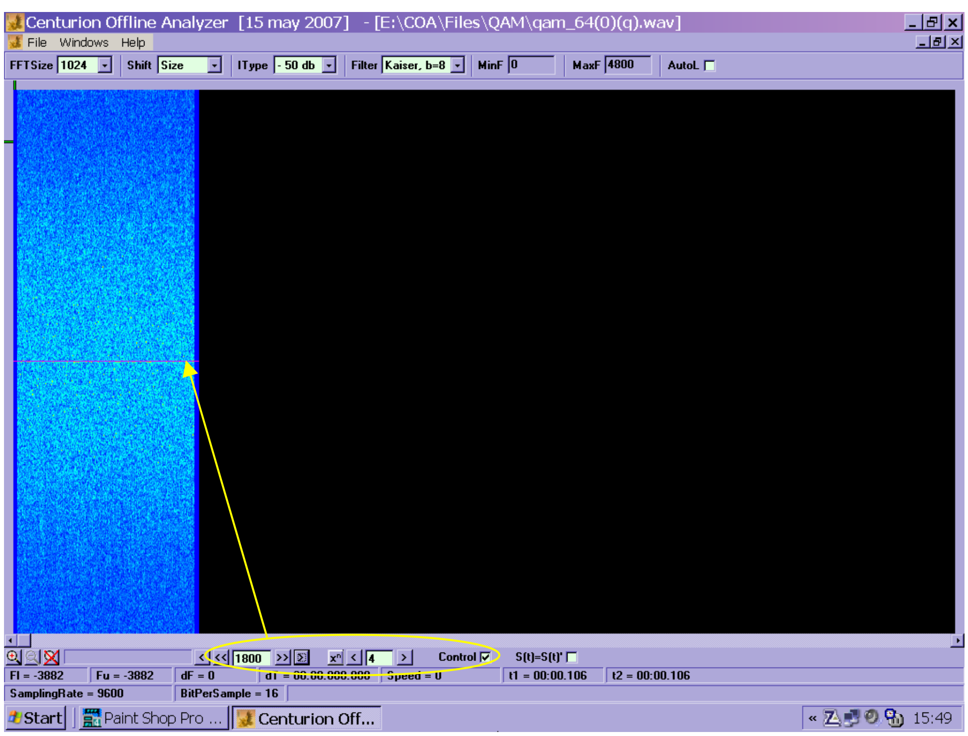
19.9.3 QAM-64

19.9.3.1 Determining Symbol Rate, Carrier and initial N-ary



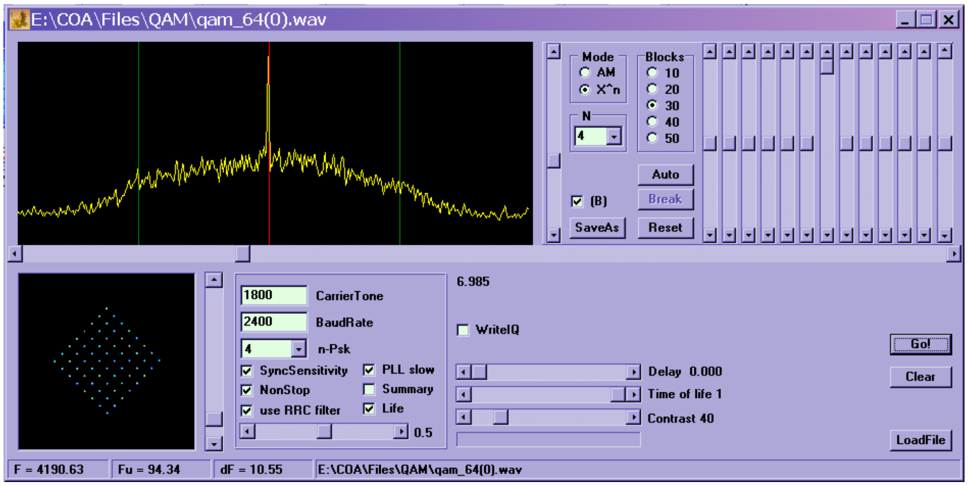
Two windows created from the source file.

u window indicates symbol rate of 2400.



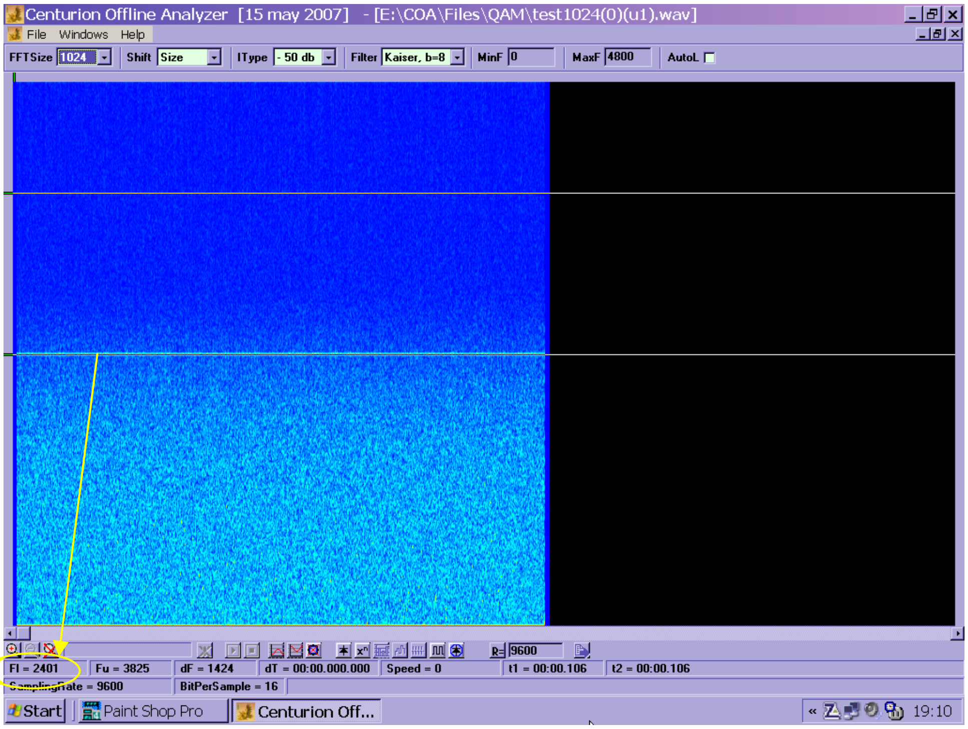
q window indicates carrier frequency, and initial n-ary.

19.9.3.2 Determining n-ary



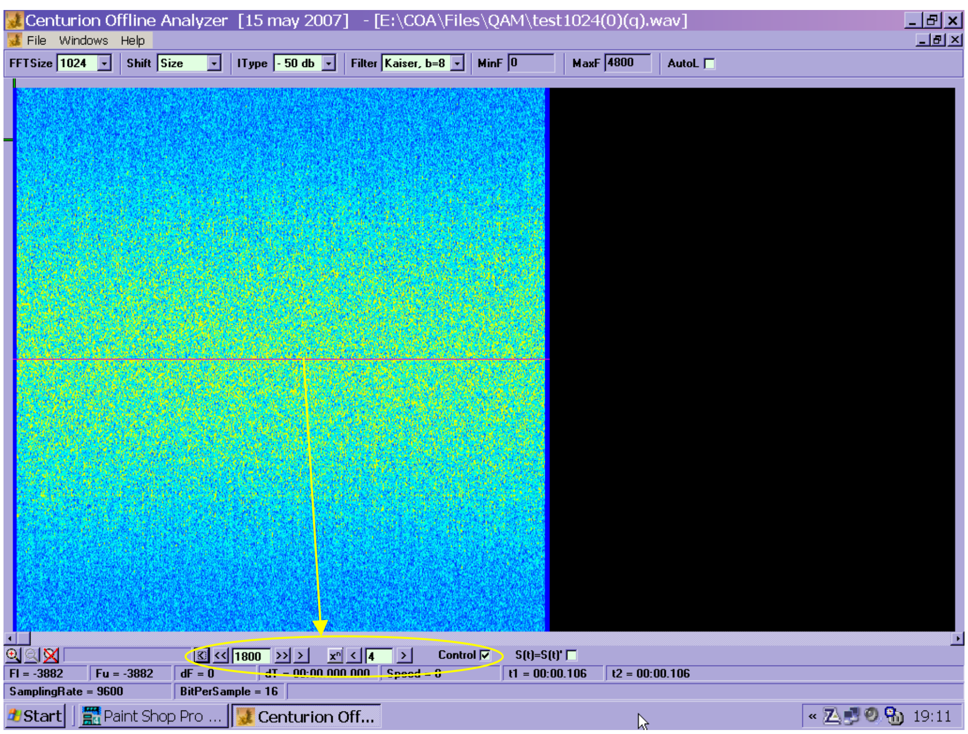
19.9.4 QAM-1024

19.9.4.1 Determining Symbol Rate, Carrier and initial N-ary



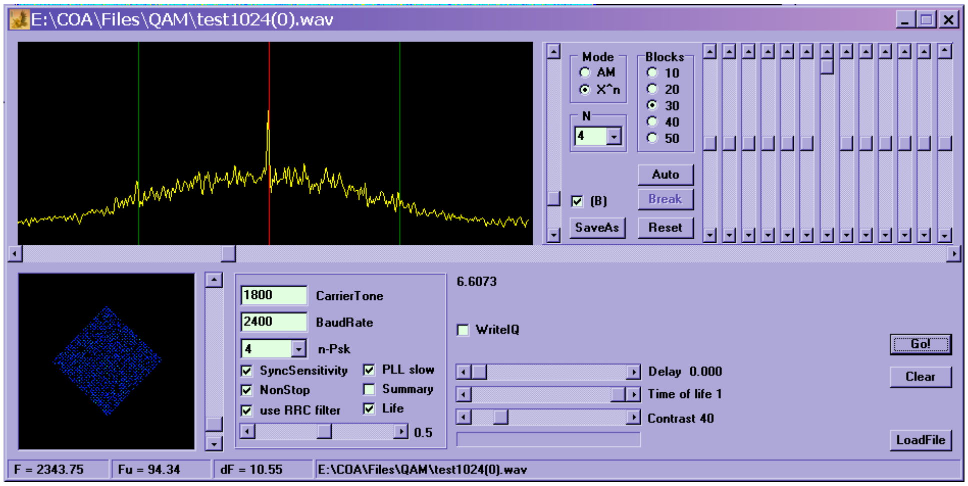
Two windows created from the source file.

u window indicates symbol rate of 2400.



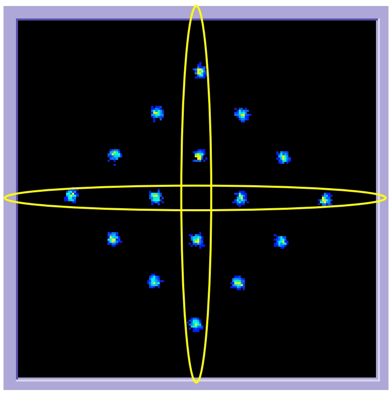
q window indicates carrier frequency, and initial n-ary.

19.9.4.2 Determining n-ary

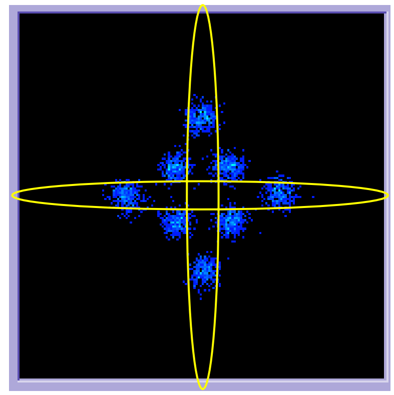


19.9.5 Notes on QAM

19.9.5.1 QAM constellations.



'True' QAM (16QAM)



V29 modem

Note the symbols lying within the crosshairs in 'true' QAM and compare this with the V29 modem constellation.

19.9.5.2 Ghost lines.

Refer to Section 19.9.2.2.

In QAM signals, especially if not of high quality one will see in S(t)^4 the carrier without adjacent lines developing. If the QAM signal is of high quality only 16QAM will have clear lines developing.

For 32QAM, 64QAM, 128QAM etc., the adjacent lines in S(t)^4 are an exception and not correct; they are ordinarily not visible.

19.9.5.3 n-PSK in the Phase Viewer

For all QAM signals, this value must be 4.

19.9.5.4 QAM on HF, VHF, etc.

QAM is very sensitive to distortion and practical usage on HF does not exceed 32QAM.

However Mil-Std 188-110B, and it's derivatives STANAG 4438 and STANAG 4539, together with some other proprietary modems from Rockwell-Collins, Harris and other Laboratories and research firms have all had 64QAM up to 57-64 kbps on air on HF. Though 64QAM has been tested on long-haul paths in excellent propagation conditions, most are used in short-haul, point-point circuits and as such the low (barely audible) noise field will be missed by most monitors due to equipment and experience limitations.

What constitutes a High Data Rate (HDR) system? One where the carrier/symbol rate ratio is <=1.2.

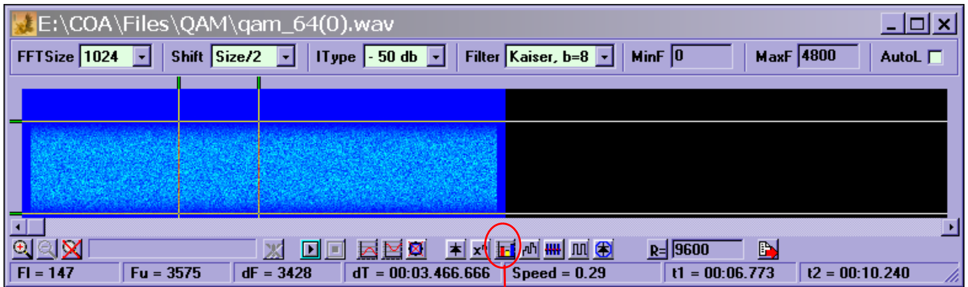
eg 1800Hz/2400 symbols/sec = 0.75 is considered an HDR system.

OFDM (*eg Non-HDR) single channel systems may use either 32QAM * 32 tone, or greater. Typical carrier/symbol rate for one OFDM channel is 10-15, and higher. Maybe "HDR" is not an appropriate term since it is really baud rate and data/symbol rates one deals with.

32QAM and higher order modulations using a single carrier ordinarily are seen in wireline, optical carriers (WDM etc) and VHF and higher applications.

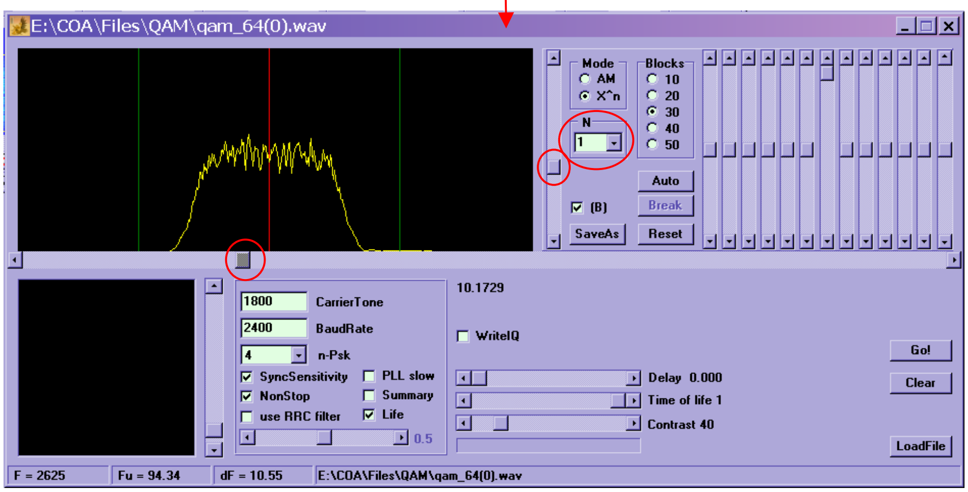
19.9.5.5 Distortion/slanting.

Before assessing distortion/slanting we must consider the ideal signal.



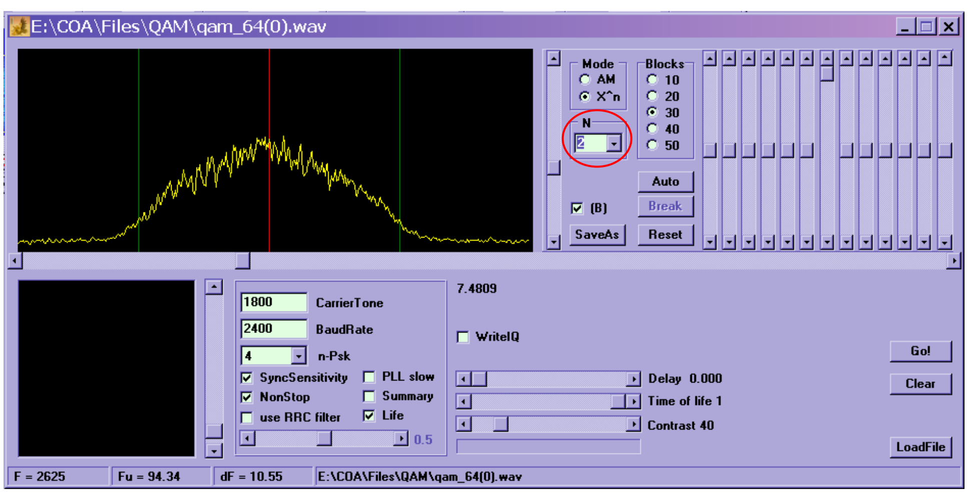
Having prepared and delineated the source window o note that the noise field is of even density.

Call the viewer.



After LoadFile and setting the horizontal and vertical sliders set N=1.

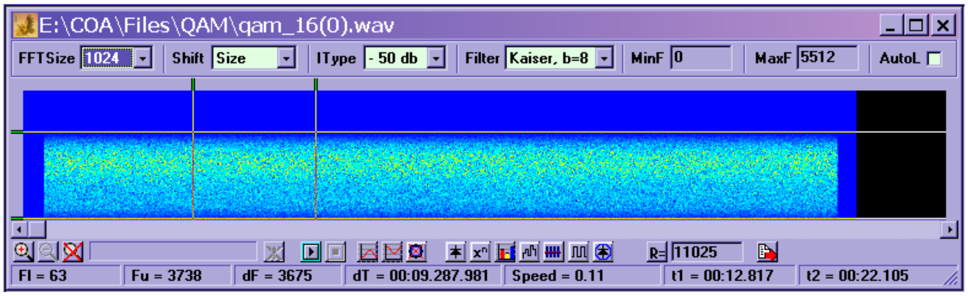
Note the signal amplitude-frequency profile in the window.
It is symmetrical about the red marker indicating good quality.



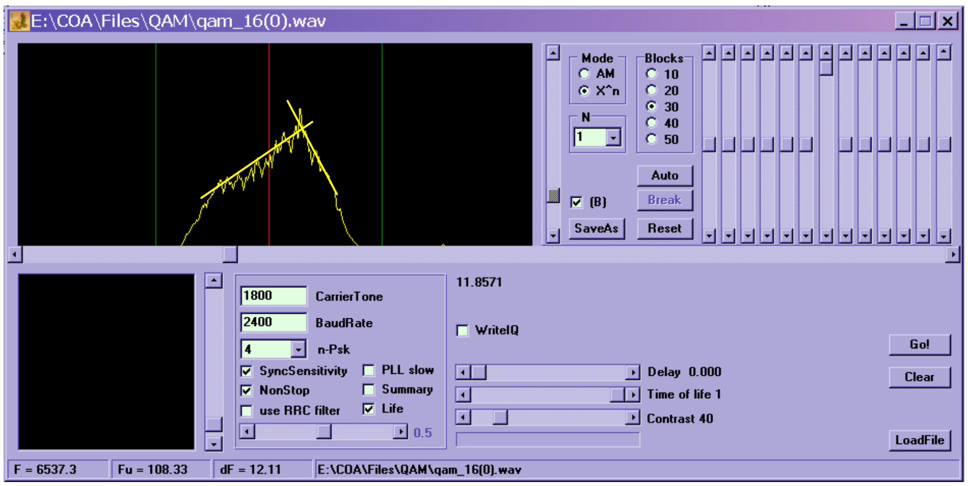
Set N=2.

The profile continues to be symmetrical and will also on N=4 (**S(t)^4**). Refer Section 19.9.3.2

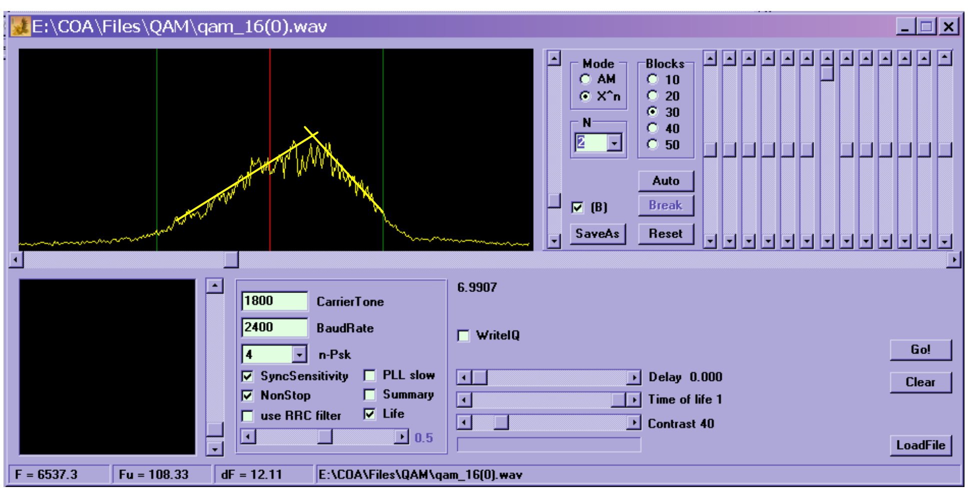
Turning now to a signal affected by distortion.



Note in the source window there is not an even level across the noise field. It tends here to be stronger at the higher frequencies.



In the Viewer at N=1 and



at N=2 the profile is no longer symmetrical with pronounced, and unbalanced slants n being seen.

In keeping with the indications in the source window these two viewer images show a bias to a stronger signal on the higher frequencies.

This indicates non-linear Amplitude-Frequency distortion.

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19.9.5.6 RRC (Root-Raised Cosine) filtering.

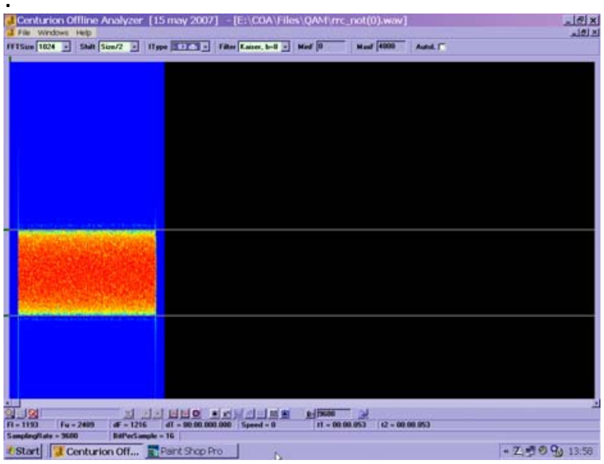
RRC filtering is always used on the transmitter when an optimized (bandwidth and filling of spectrum) form of signal is required. Ordinarily this would be an HDR system with a single carrier; but not always.

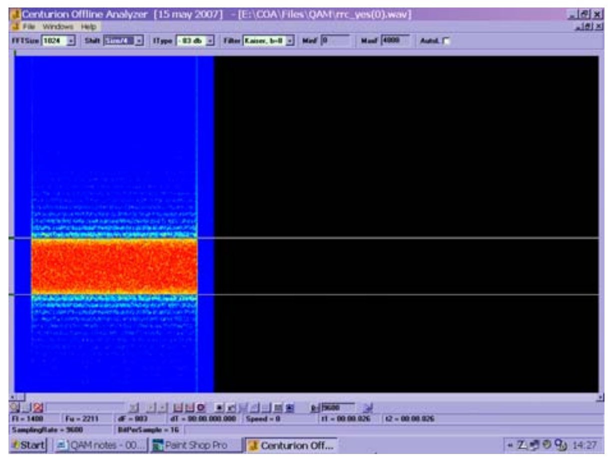
Easy to implement for a standard phone channel (BW= ~3000Hz). Not possible is the PSK(QAM) with a symbol rate of 2400 without RRC which needs a bandwidth of 4800Hz (2400*2).

RRC solves this problem. If RRC used the bandwidth is typically 2800-2900Hz for the same 2400 symbol/sec signal. The theoretical limit = symbol rate.

This can be shown graphically in the two following sets of images. The signal is a PSK-4 with 1800Hz carrier and symbol rate of 600.

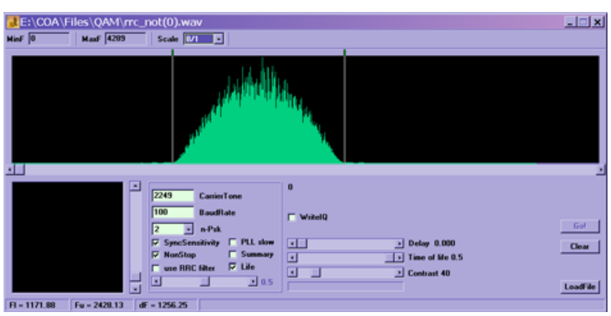
.

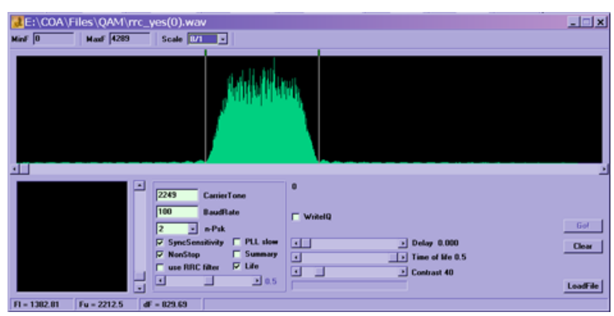




No RRC. Bandwidth ~1200Hz.

With RRC. Bandwidth ~800Hz. This is very near to the theoretical limit of 600Hz.





Without RRC (on Left) poor use is made of frequency spectrum. With RRC (on right) better use is made of the spectrum and moreover the signal is much more compact.

RRC is only one method. The RFSM-2400 (Russian radio amateur) employs an LPF shaping filter.

However RRC is highly desirable for optimization. It is used for optimization of signal bandwidth by minimizing ISI in a channel.

For a full positive effect RRC should be implemented on both the transmitter and the receiver.

Phase Viewers tend to have RRC ON permanently with an fixed α (Alpha) of 0.5; but this need not be so.

In general if the program uses an adaptive ISI-ISD corrector RRC may then or not be needed but this requires prior information relating to the signal (carrier, symbol rate, modulation type, etc).

For analysis RRC needs to be optional and the alpha variable. In reality the RRC filter helps in achieving ideal QAM signals.

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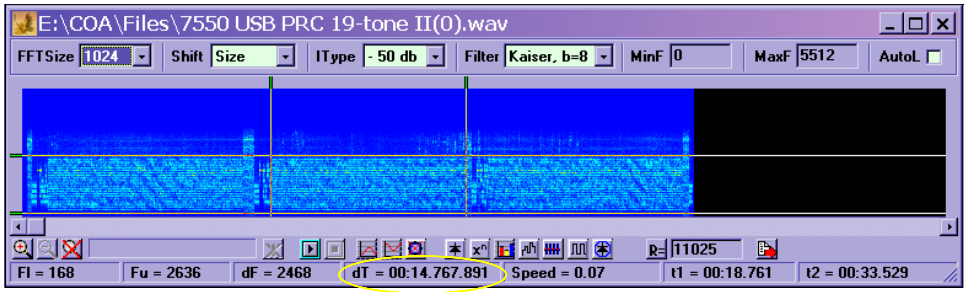
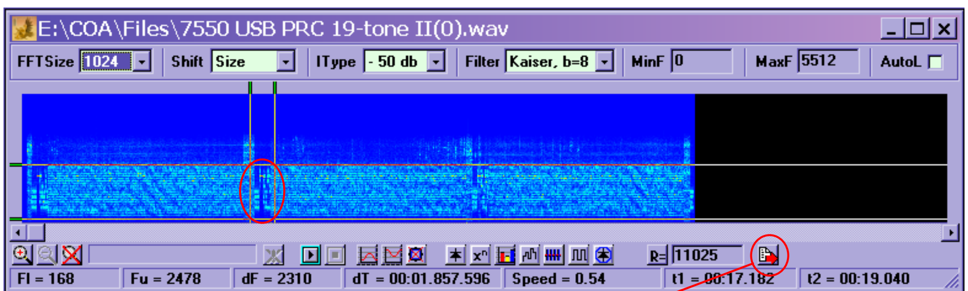
19.10 Analyzing multi-mode bursts.

These generally have a header/preamble before the traffic section. Each part must be analyzed separately. This example outlines the approach.

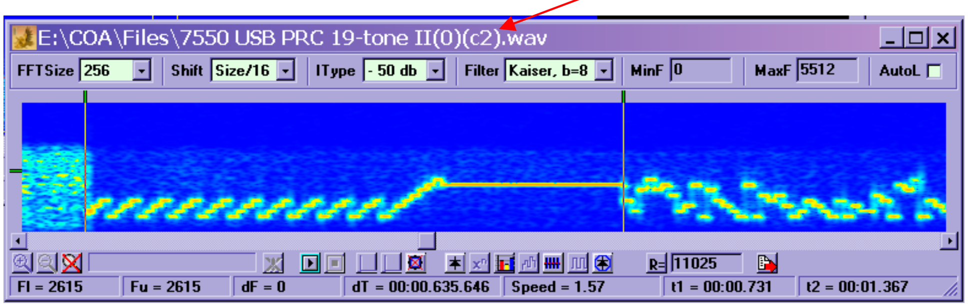


Load and prepare the signal. Signal has regular length bursts with short MFSK header/preamble and 14.77 Sec ODFM traffic burst.

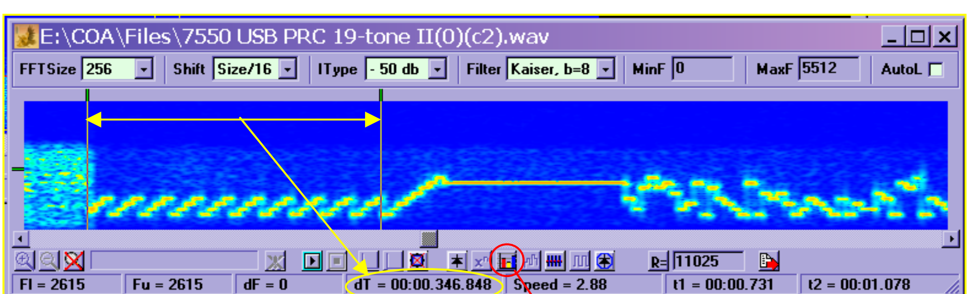
19.10.1 Analyze the header/preamble.



Delineate the header/preamble section and create a copy for working.

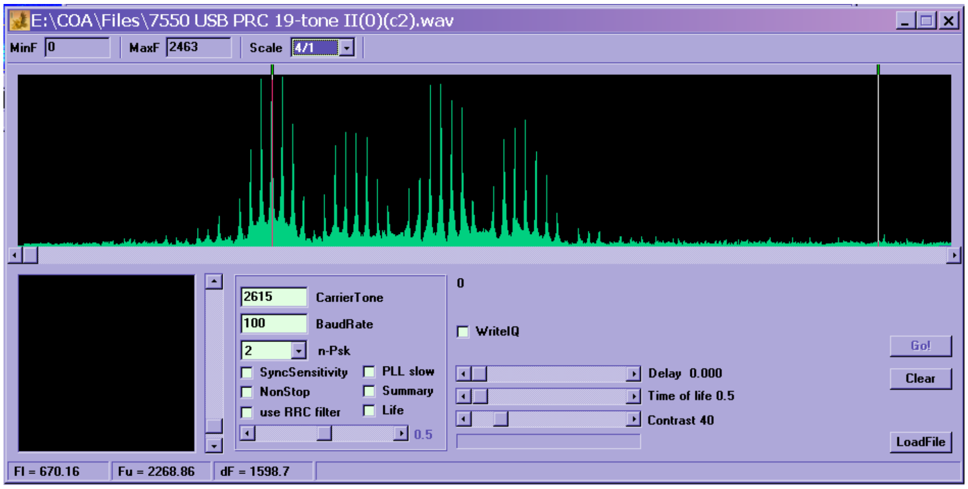


Reduce the FFTSize to improve clarity. The header section consists of two parts 636 mS in total.

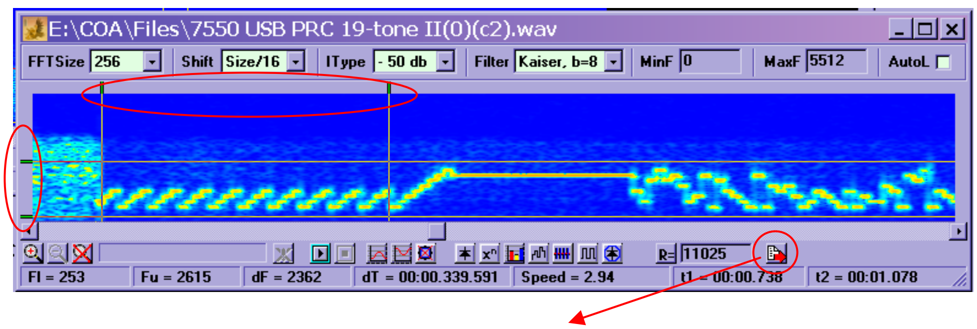


The first section (347mS) consists of four tones stepping in sequences then repeating. After 10 ramps there is a single ramp through 8 tones.

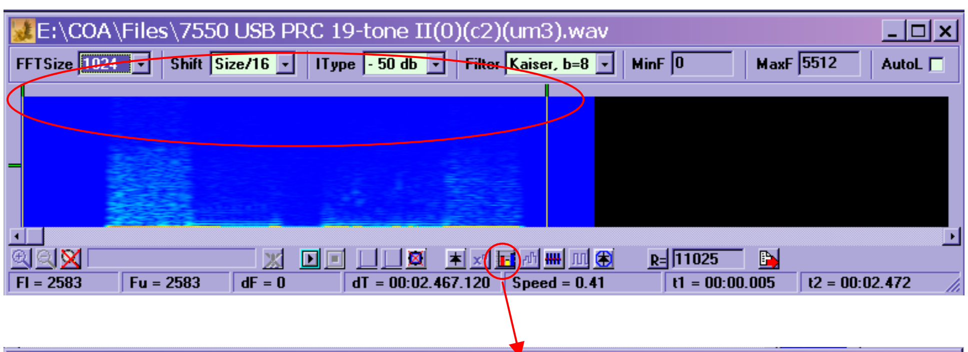
With the ramped tones delineated call the High ResolutionModule.



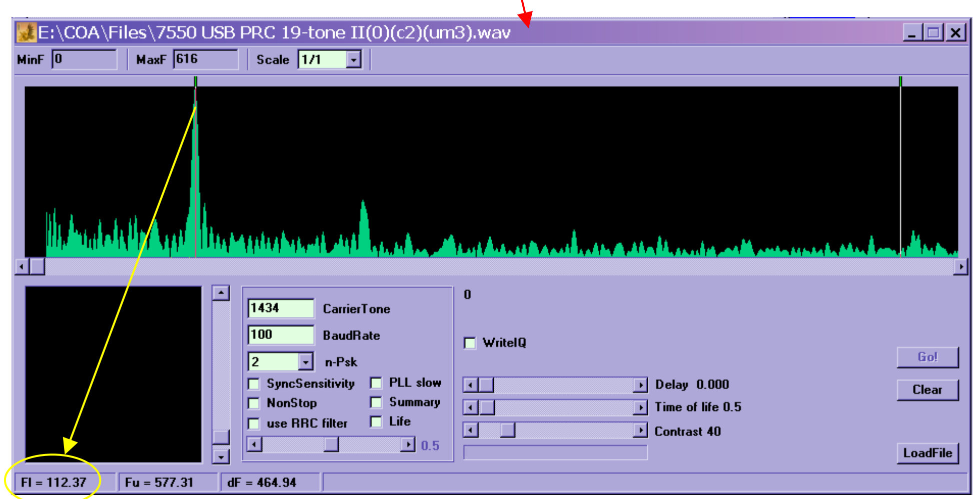
The four tones can be measured (670 893 1116 1339 Hz) using the vertical markers. The tone separation is 223 Hz.



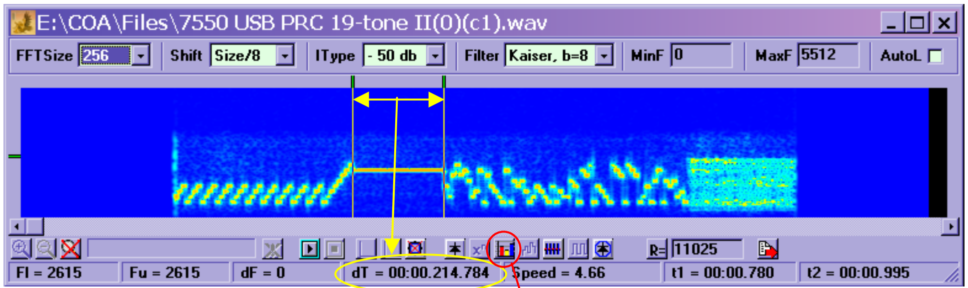
Return to the parent working window and delineate with vertical and horizontal markers. Call the Modified Quadrature Amplitude Detection module.



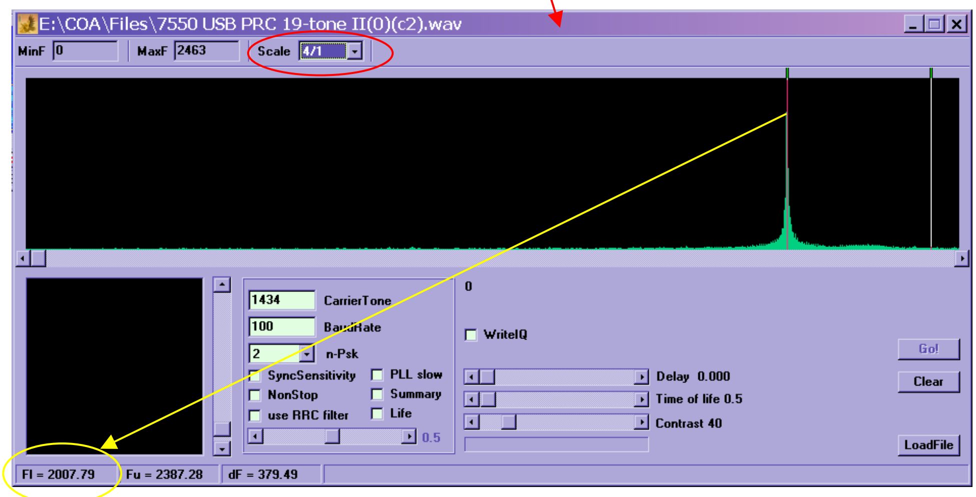
In the **um** results window delineate with vertical markers and call High Resolution Module.



Align Fl marker with longest spike to obtain the baudrate (112 bd) of this section.



The next second is a single tone lasting 215mS. Delineate and call the High Resolution module.



Align the Fl marker with this tone to measure 2008Hz. If this tone is not seen initially adjust Scale (now at 4/1) until it appears.

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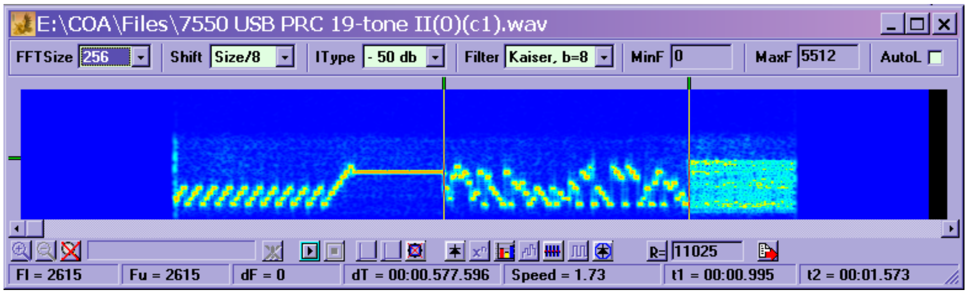
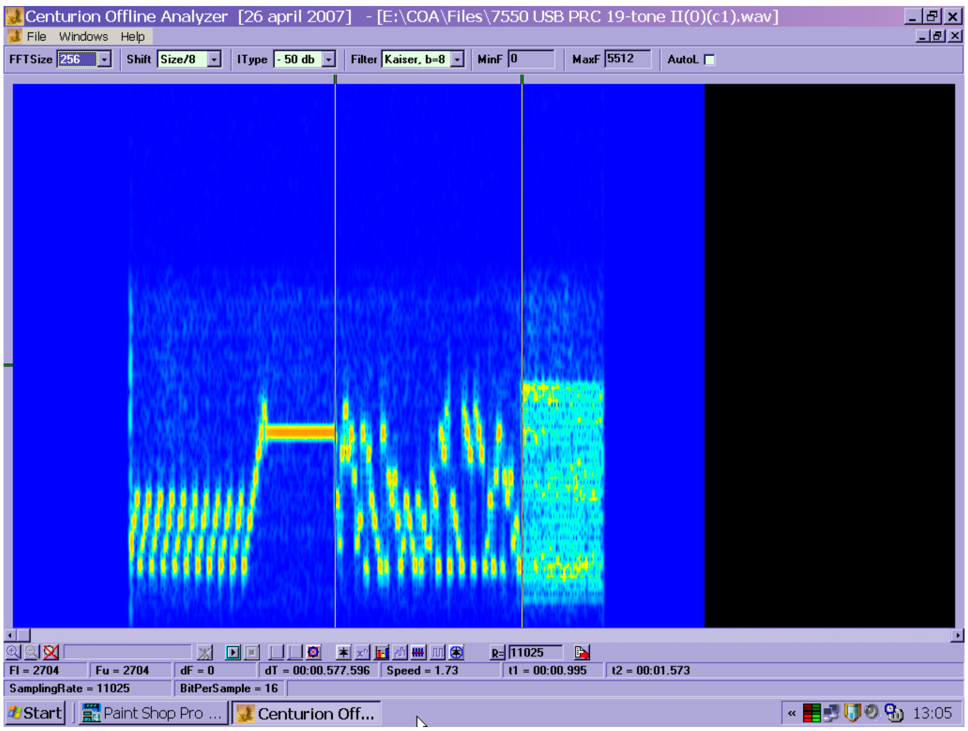
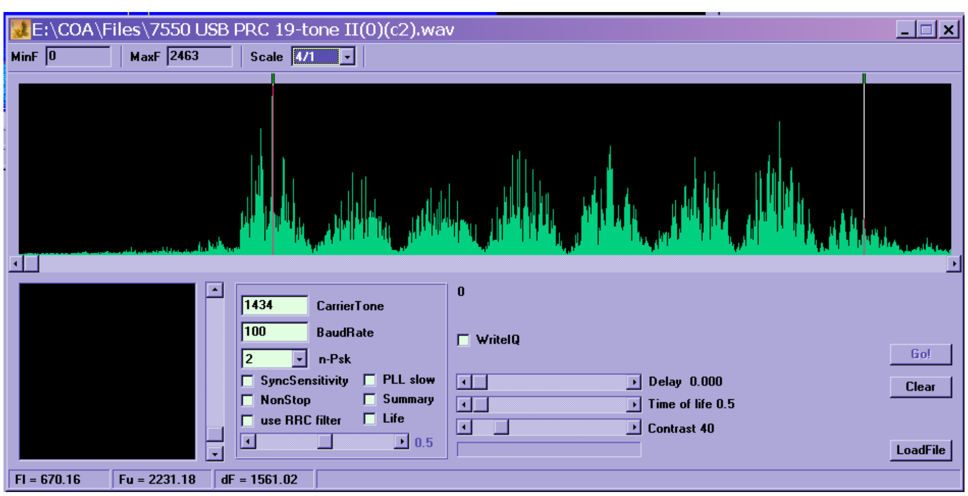


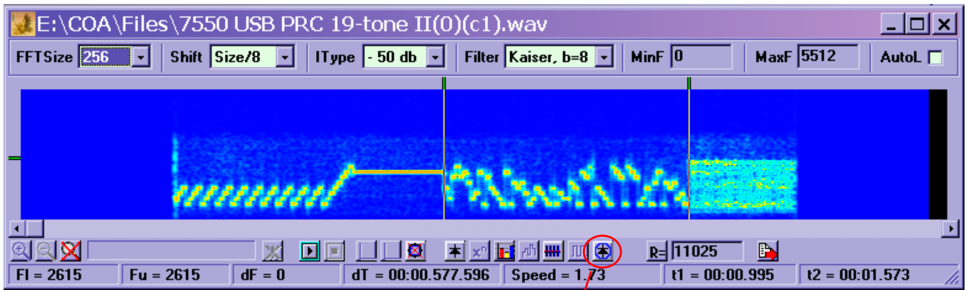
Delineate the third (MFSK) preamble section. It occupies 577.6 mS. Call High Resolution module.



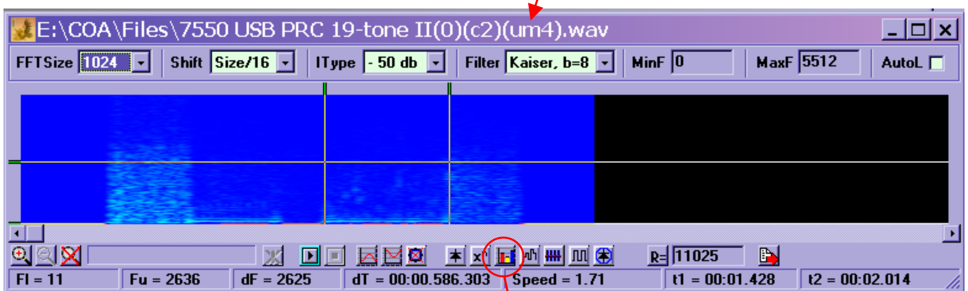
Maximizing the window will improve presentation if necessary.



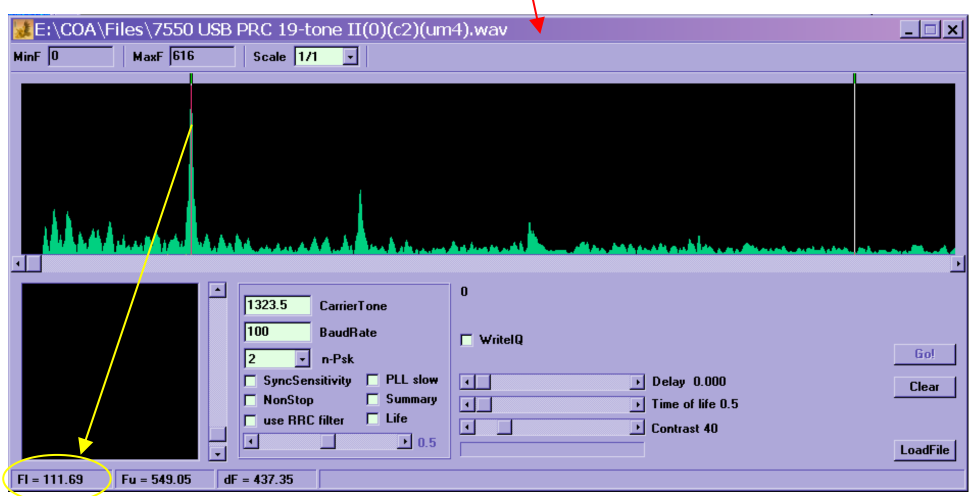
In this section eight tones can be measured (670 893 1116 1339 1562 1785 2008 2231) using the vertical markers. The tone separation is again 223Hz.



Again return to the parent working window and delineate. Call Modified Quadrature Amplitude Detection module.



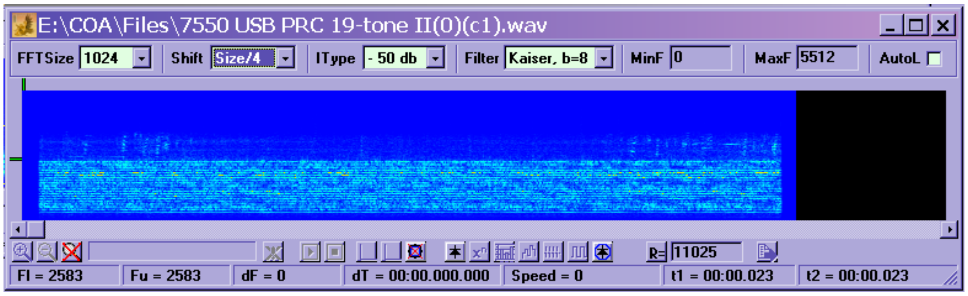
In the **um** results window delineate and call High Resolution module.



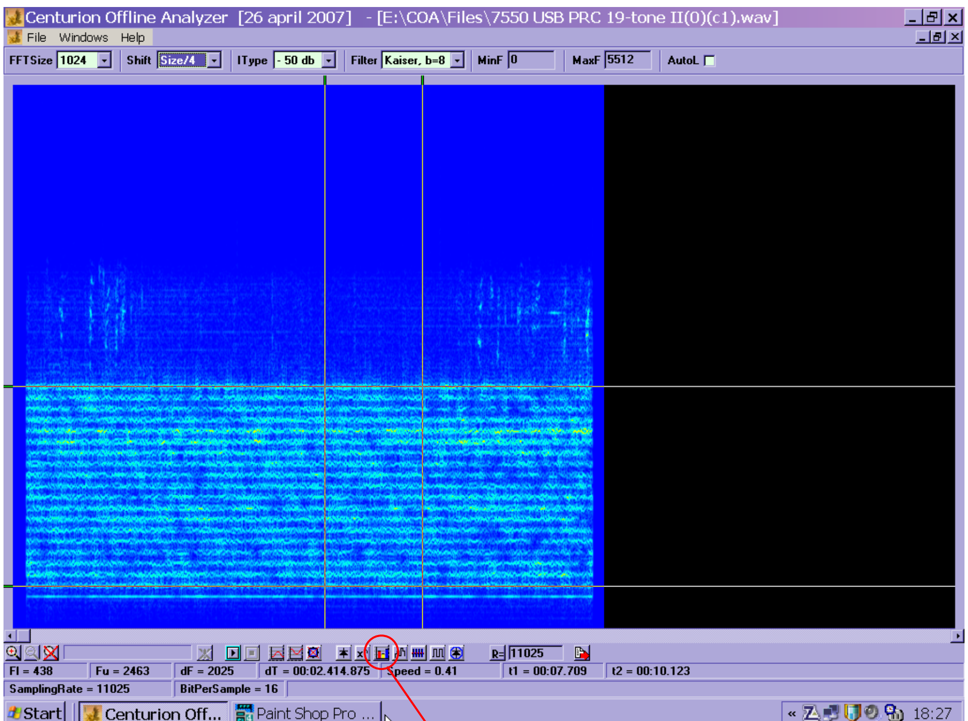
Align Fl marker with longest spike to obtain the baud rate (again 112 bd) of this section.

19.10.2 Analyze the OFDM traffic section.

19.10.2.1 Determine tone structure.

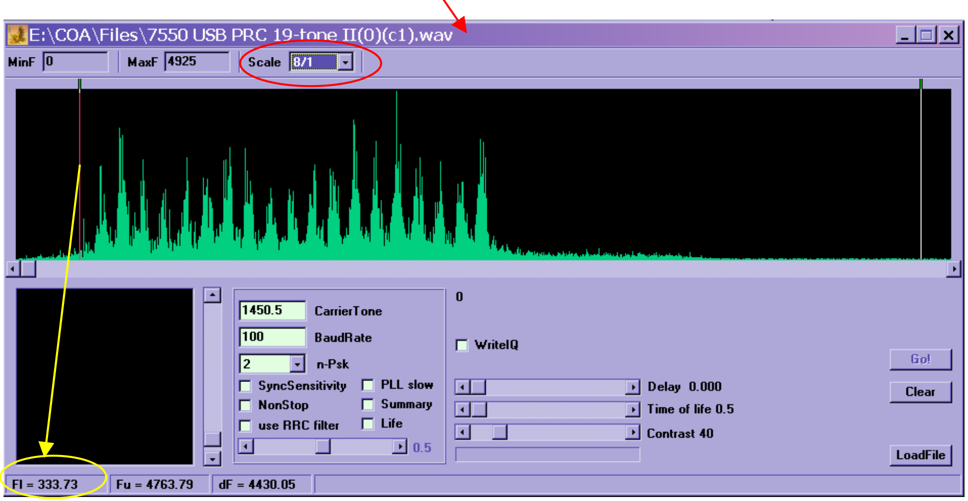


Extract and copy a section of OFDM.



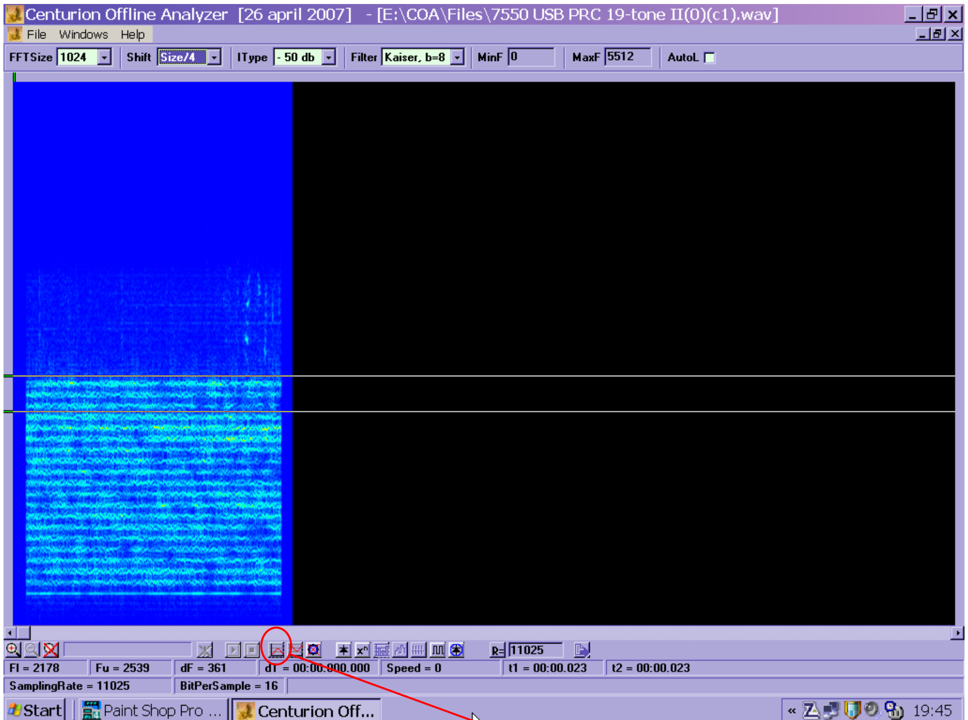
Maximize the window for more clarity.
From this is seen 19 modulated channels lying between approximately 438 Hz and 2463 Hz. Note also a lower unmodulated pilot tone.

Delineate a section and call the High Resolution module.

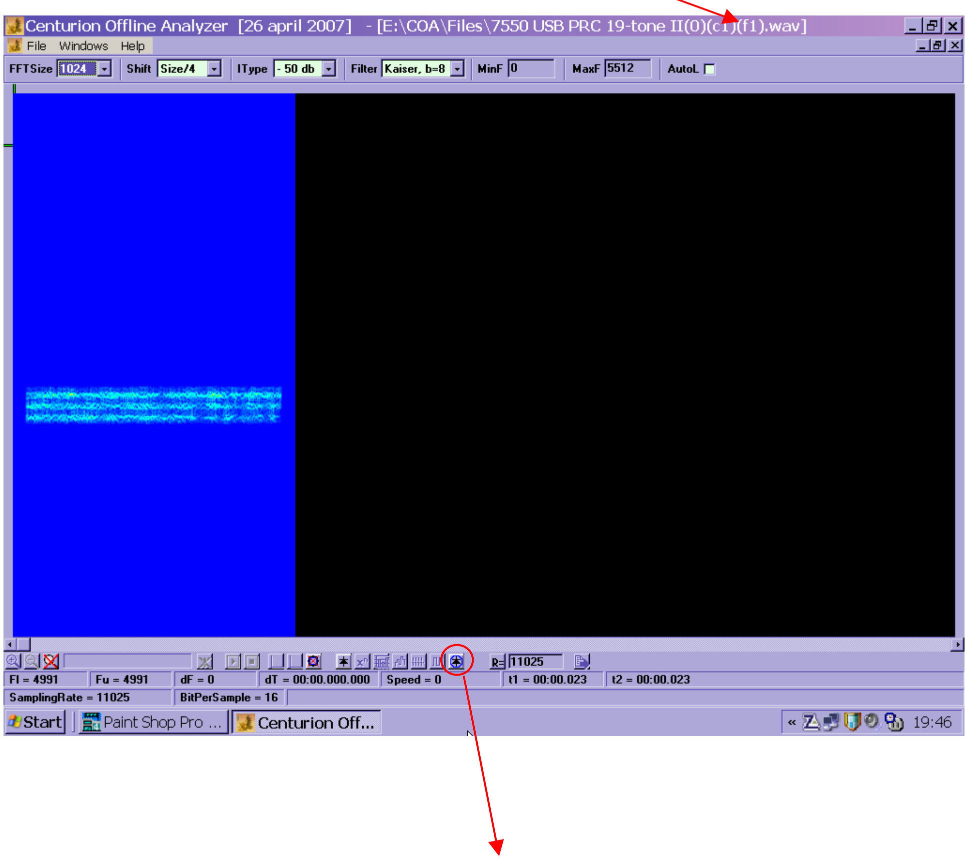


Adjust Scale to show all tones. The pilot tone is measured using the Fl marker to show 334Hz. 19 modulated channels are seen. From ~457 to ~2454 Hz. Approx tone separation is 2454-457/19-1 = 111 Hz.

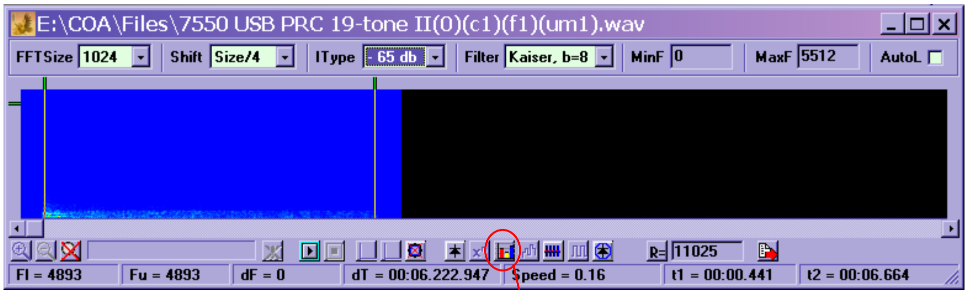
19.10.2.2 Determine Symbol Rate



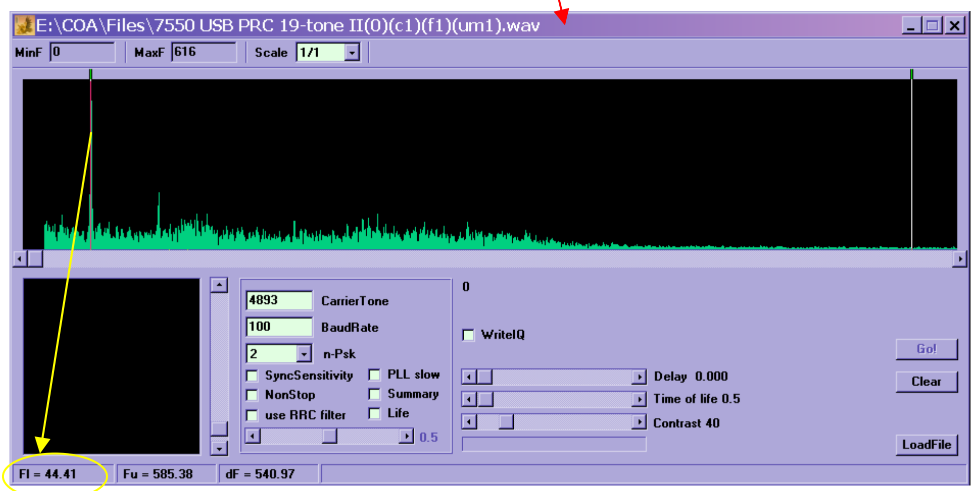
Delineate 2 or 3 channels with the horizontal marks. Call Filter.



With (three) channels isolated call the Modified Quadrature Amplitude Detection module.

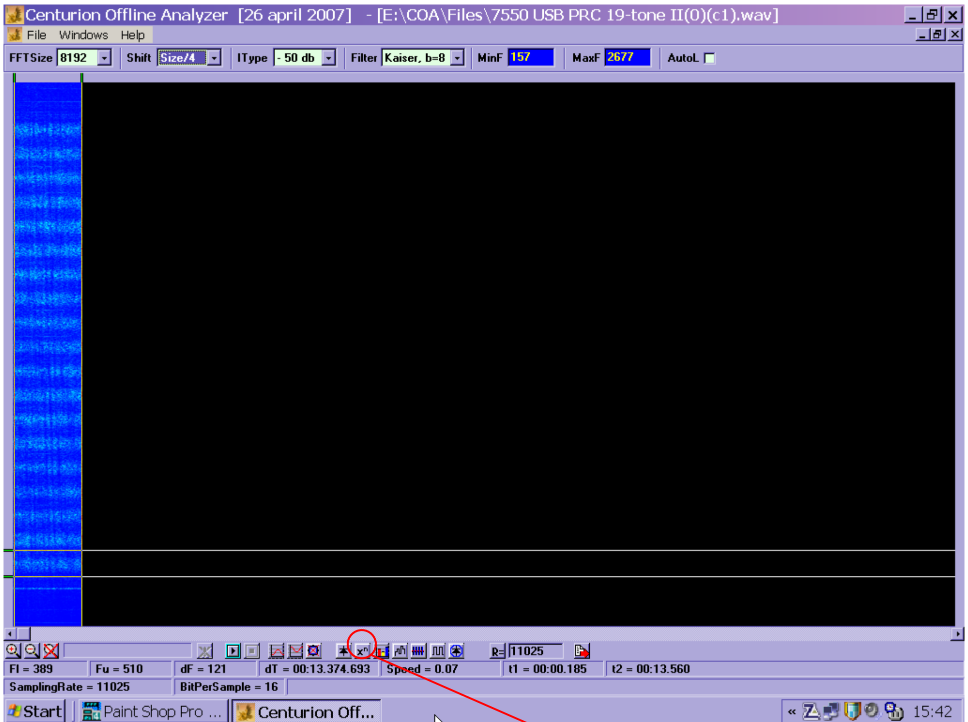


Delineate section in **um** results window and call the High Resolution module.

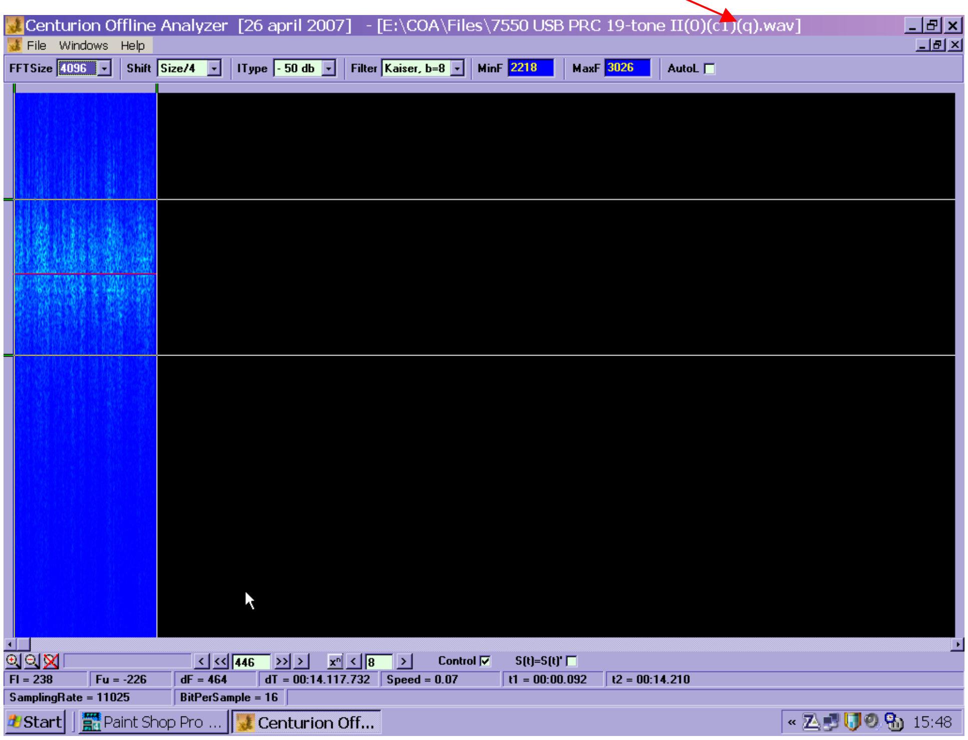


Align the Fl marker with the longest spike to measure the symbol rate (44.4 symbols/sec).

19.10.2.3 Determine key channel frequencies and modulation.

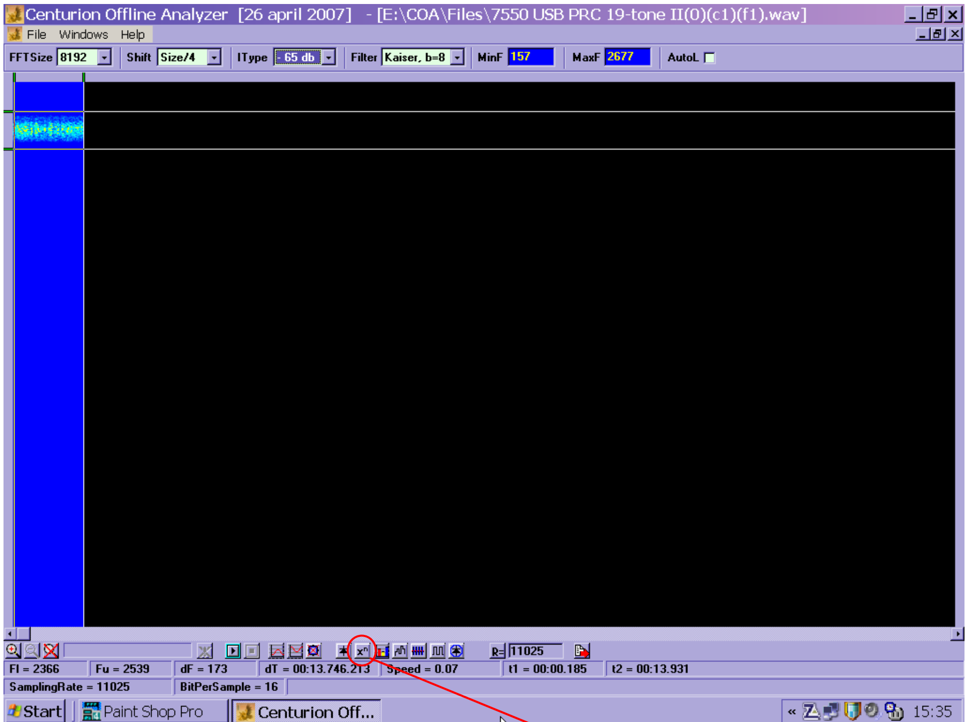


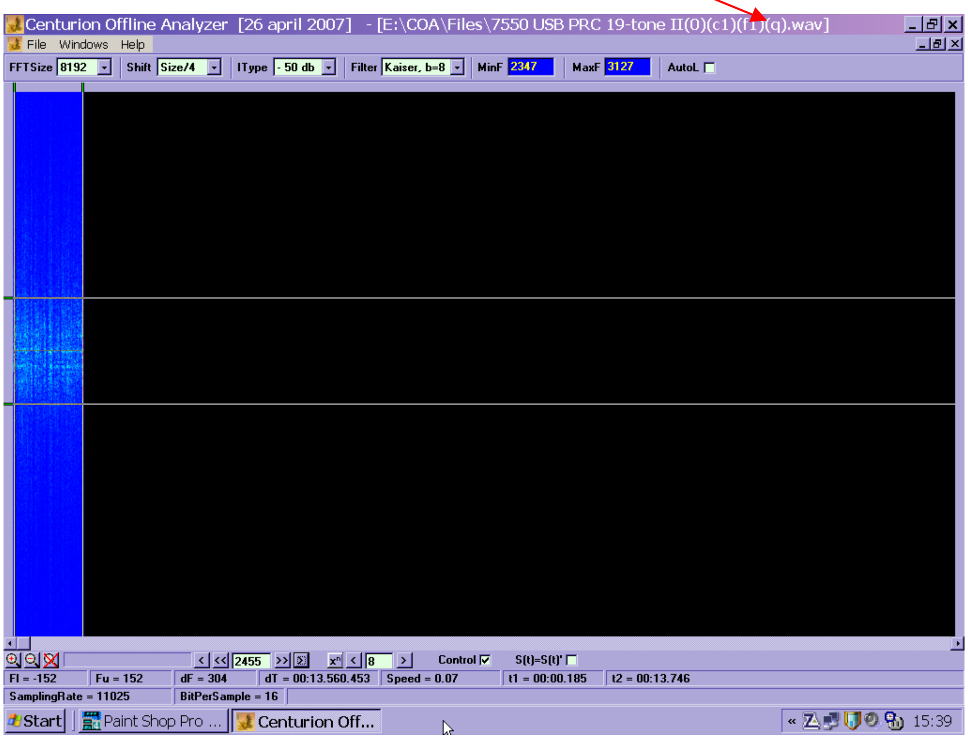
Isolate (filter) the lowest channel using the horizontal markers. Call the Involutions module (**X^n**).



In the **q** window adjust zooming (and possibly increase FFTSize) to display the symbol rate line and it's adjacent lines. If not seen test for n-ary values 2, 4, 8, 16 (in this case 8). Check Control and adjust the control line value to align with symbol line (center of trio). Click **X^n** after each change.
Channel value is 446Hz.

Isolate (filter) the top channel and repeat the exercise.

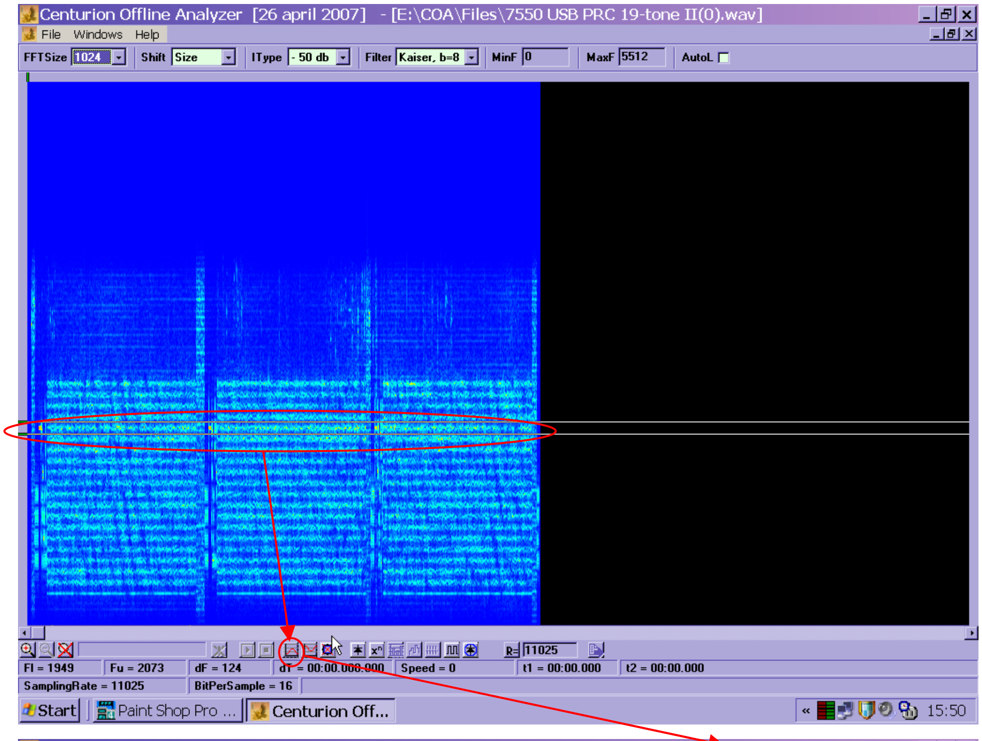




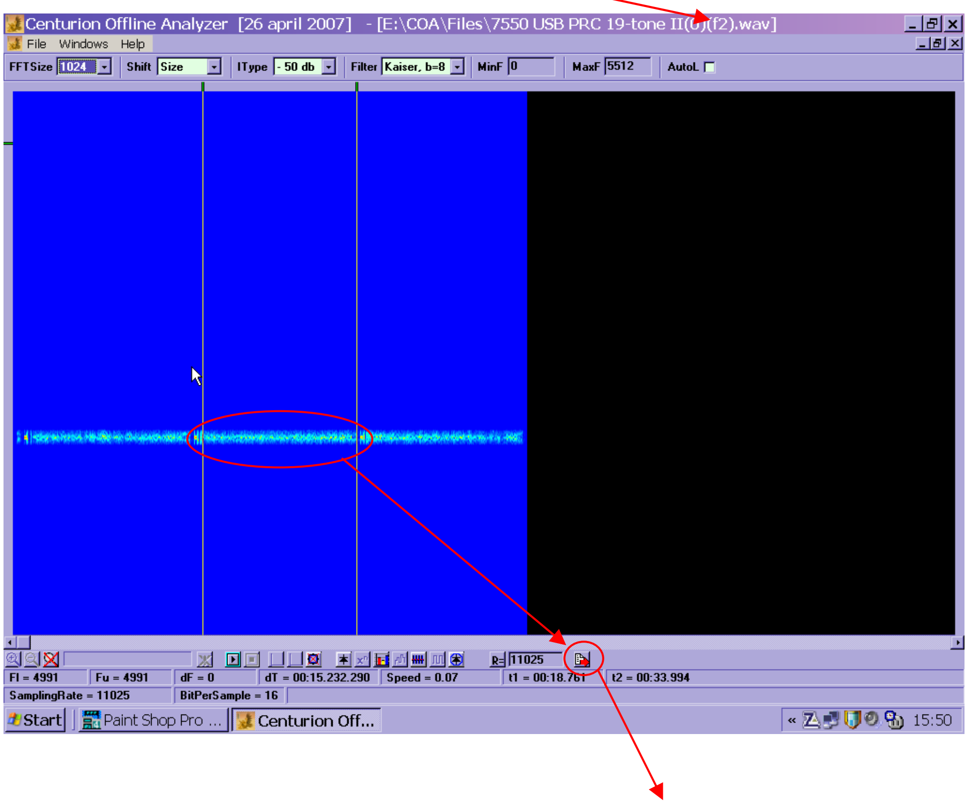
Again the phase system is 8-ary and the channel frequency is 2455Hz.

With the outer tones accurately measured the tone separation is therefore 2455-446/19-1 = 112Hz.

19.10.2.4 Display constellation.



Isolate (filter) the best channel.



Delineate a section (e.g. one burst length) and copy to a new working window.

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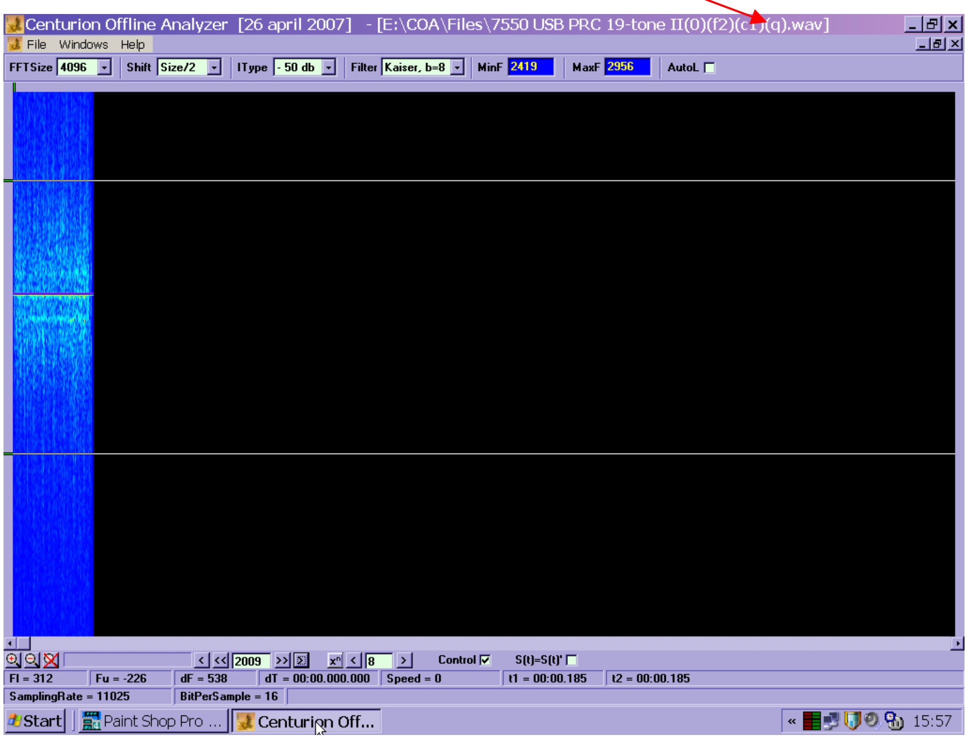
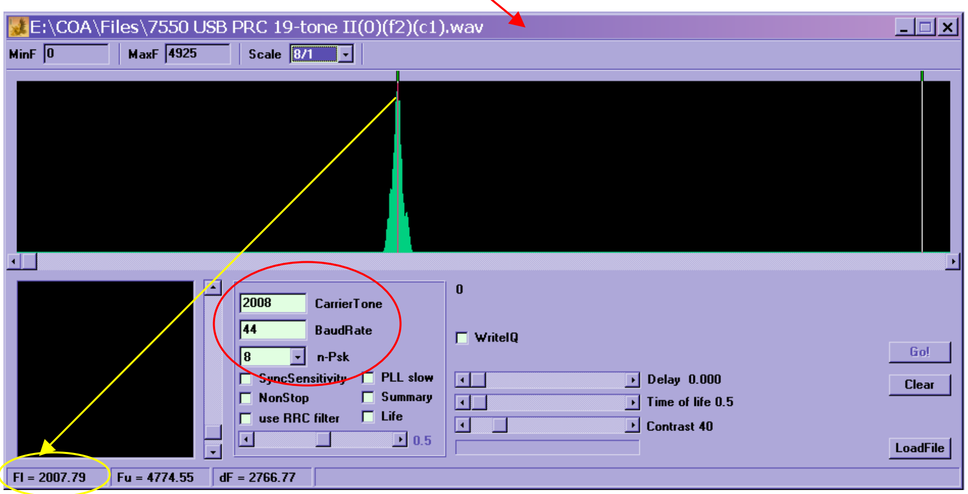
Call the Involutions module (X^n).



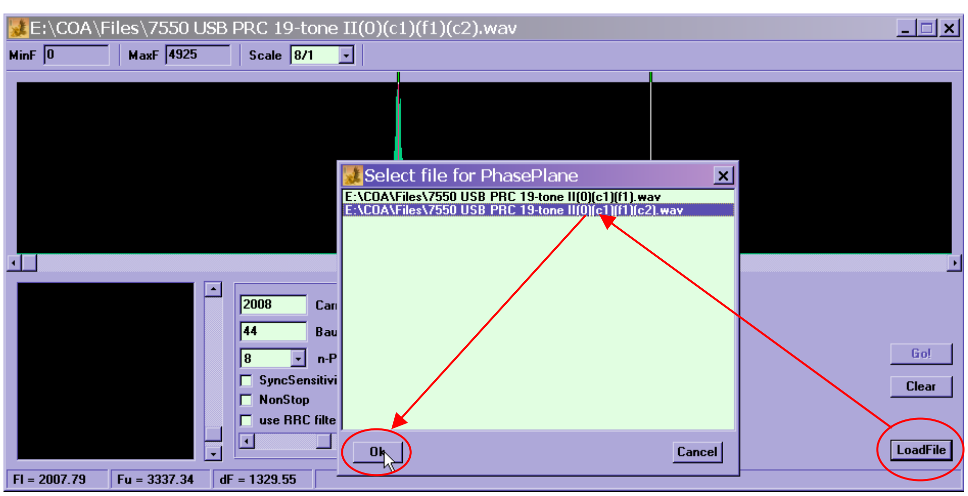
Determine the channel frequency and n-ary as before. In this case 2009Hz and 8-ary.

Return to parent copy and delineate. Call Phase Viewer.

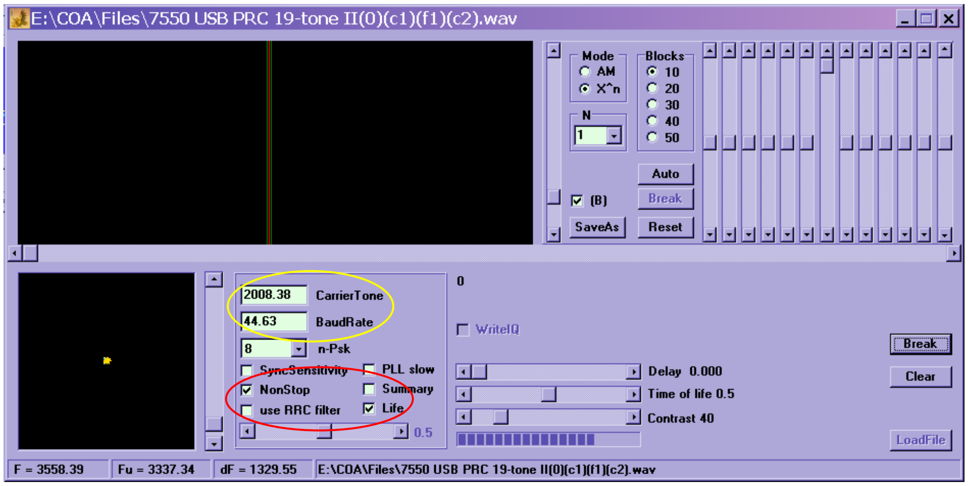


Adjust Scale until channel spike appears. This confirms by aligning vertical marker Fl that the channel frequency is 2008.

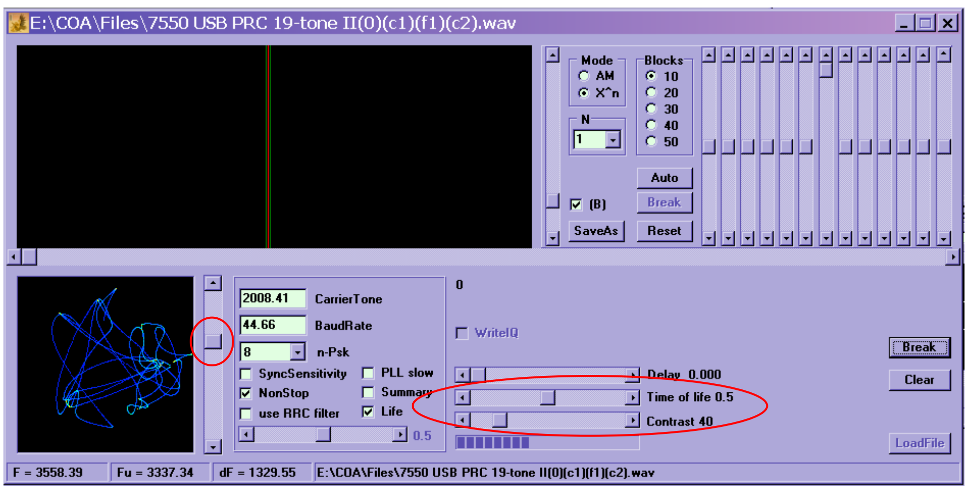
Enter values (as integers) already determined for Carrier Tone, Symbol rate and n-PSK.



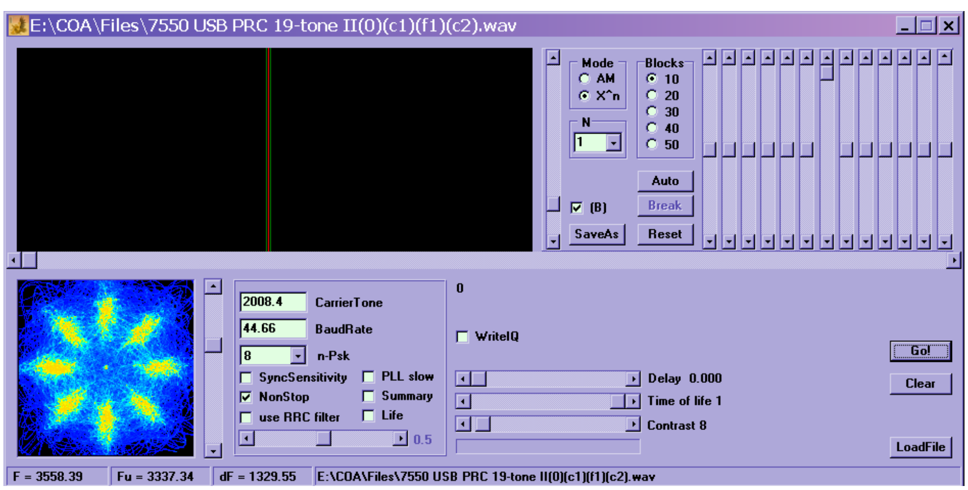
Click LoadFile, select file and click OK.



Select NonStop, Life and Go!
The Carrier Tone and Symbol Rate adjust to finer values, but the constellation is very small.



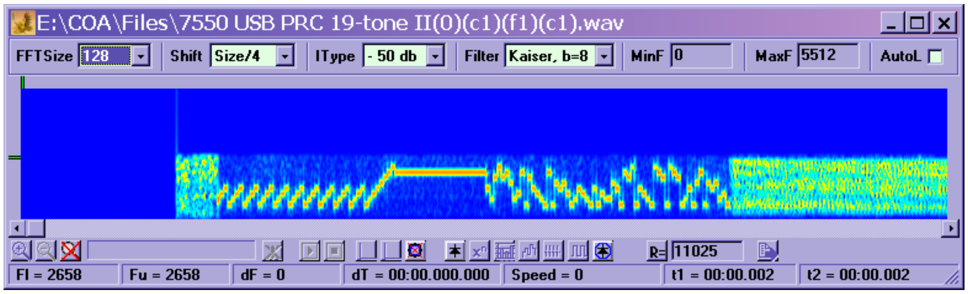
Increase the Phase Scale slider to increase the amplitude (diameter) (Application must be running).
Try changing Time of Life and contrast but it may be found that the constellation is still appears disjointed.



Alternatively un-check Life and reduce Contrast. The constellation will build over time. The constellation confirms an 8-ary system in this case.

With 19 channels, 8-PSK (3 bits per symbol) and a symbol rate of 44.66 the maximum bit rate for the system is 19 * 3 * 44.66 bps = 2545 bps.

19.10.3 MultiMode Burst Example results.



Header 636mS in total

Section 1 347mS Four tones ramping in sequence (low->high) ten times. 670/893/116/1339Hz. Tone separation 223Hz. Baud rate 112 bd.

Section 2 74mS Eight tones ramping in sequence, 670-2231Hz. tone separation 223Hz.

Section 3 215mS Single tone of 2008Hz.

Preamble 577 mS 8 tones, MFSK 670-2231Hz. Tone separation 223Hz. Baud rate 112 bd.

Signal bandwidth 1561Hz.

Traffic 14.77 Seconds

Unmodulated pilot tone 334Hz

19 OFDM channels 446 - 2455Hz

Channel separation 112Hz

Modulation 8-ary PSK

Symbol rate 44.66 symbols/sec

Signal bandwidth 2121Hz (2455-334)

With 19 channels, each 8-PSK (3bits/symbol), and symbol rate of 44.66 then
maximum bit rate = 19 * 3 * 44.66
= 2545 bps

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19.11 Analysis considerations

19.11.1 Introduction

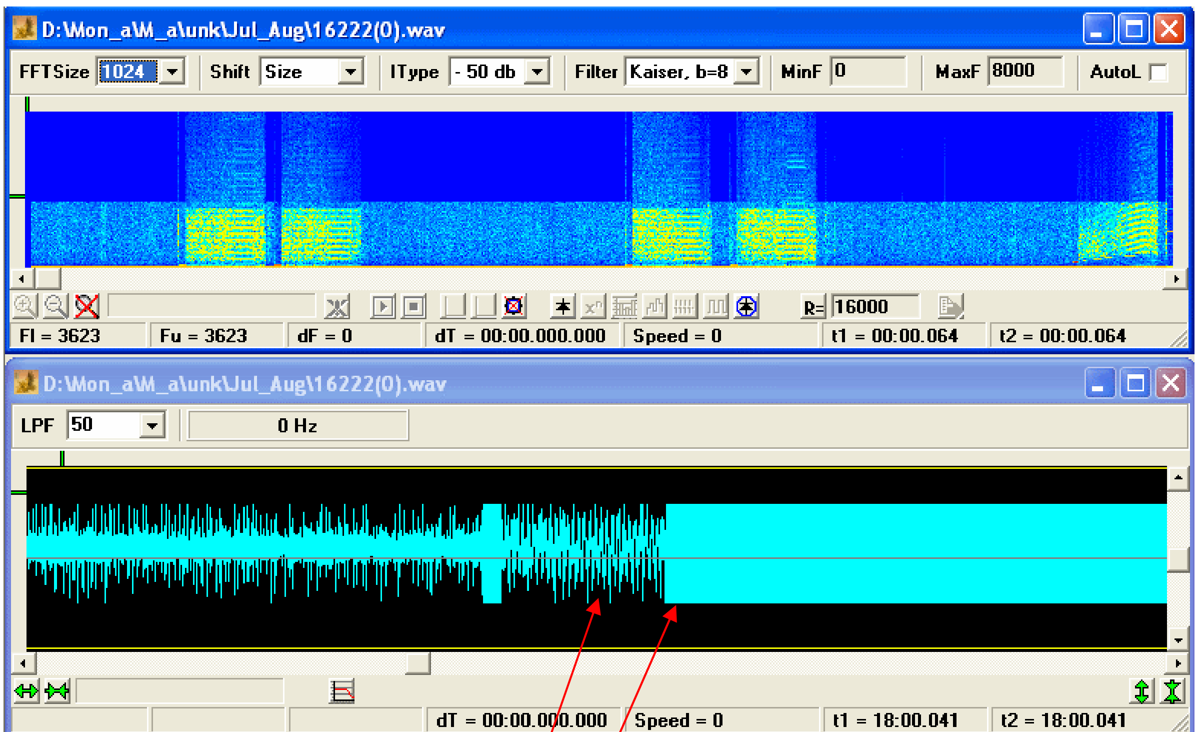
The foregone sections deal with the basics of analysis using COA. However as in all walks of life things are never straight-forward. This Section discusses a number of variants.

19.11.2 Quality considerations

19.11.2.1 Signal and noise.

The first stage in analysis is to assess the sample quality to ensure a sound basis for that analysis. Samples with poor quality should be rejected as not fit for purpose.

How to differentiate? Call the WaveForm Viewer



This is a poor record. It has ambient noise with a level virtually equal to that of the signal. The signal itself has a hard restriction ie it is clipped. This signal is not fit for purpose in an analysis.

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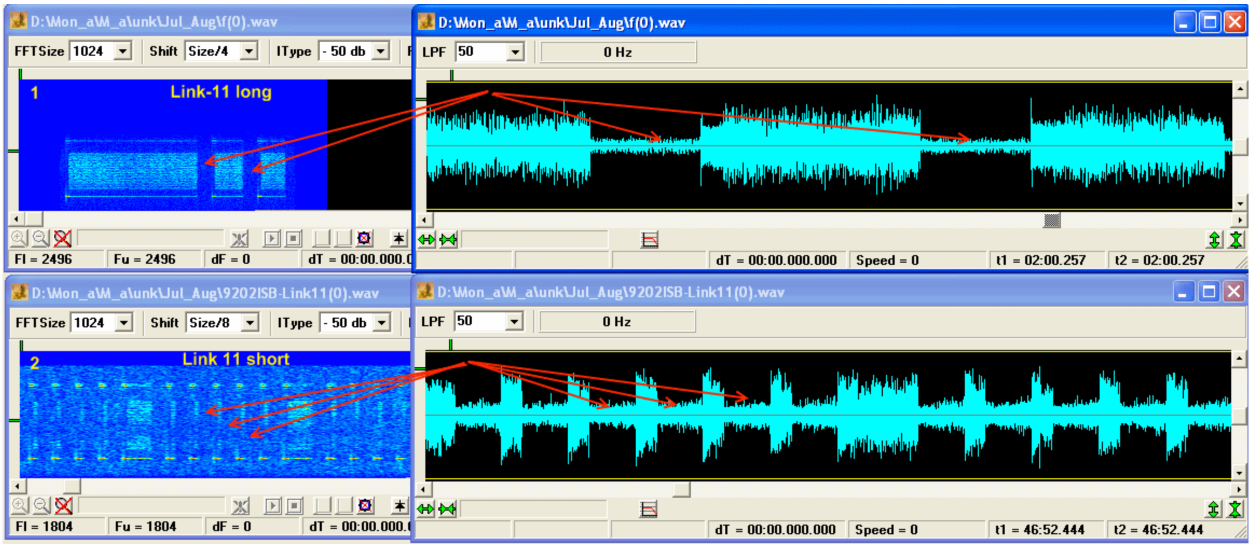
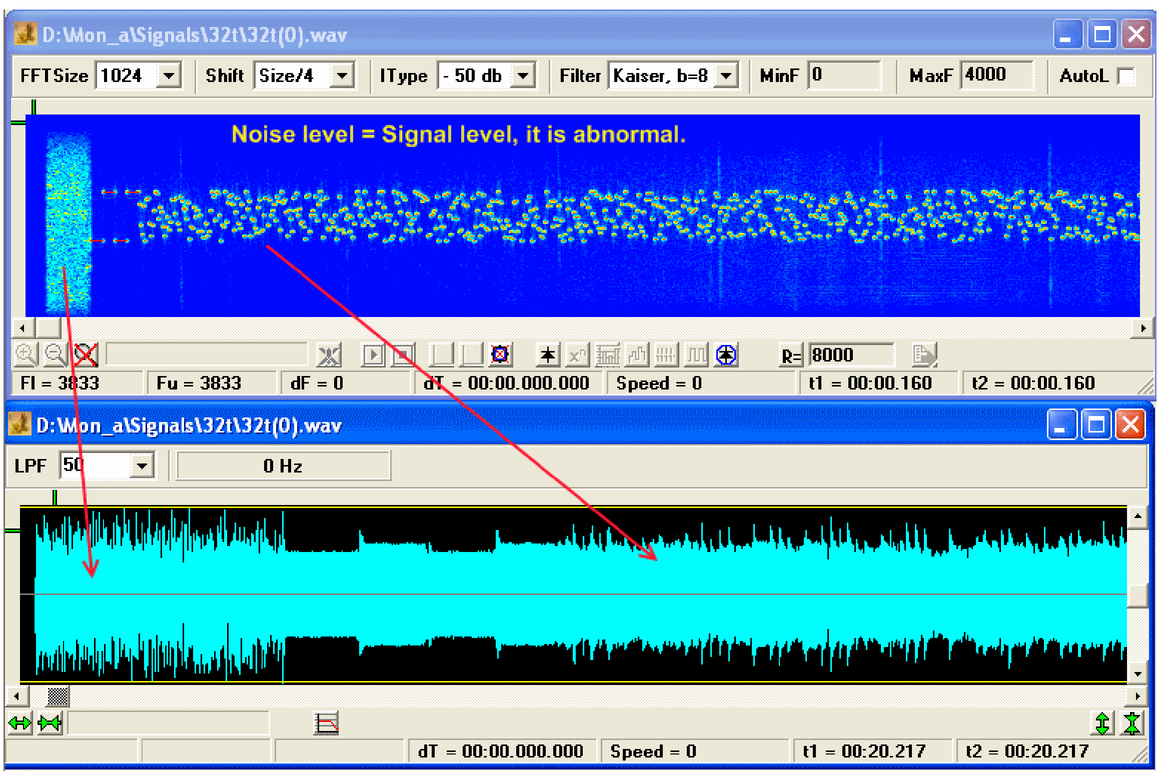


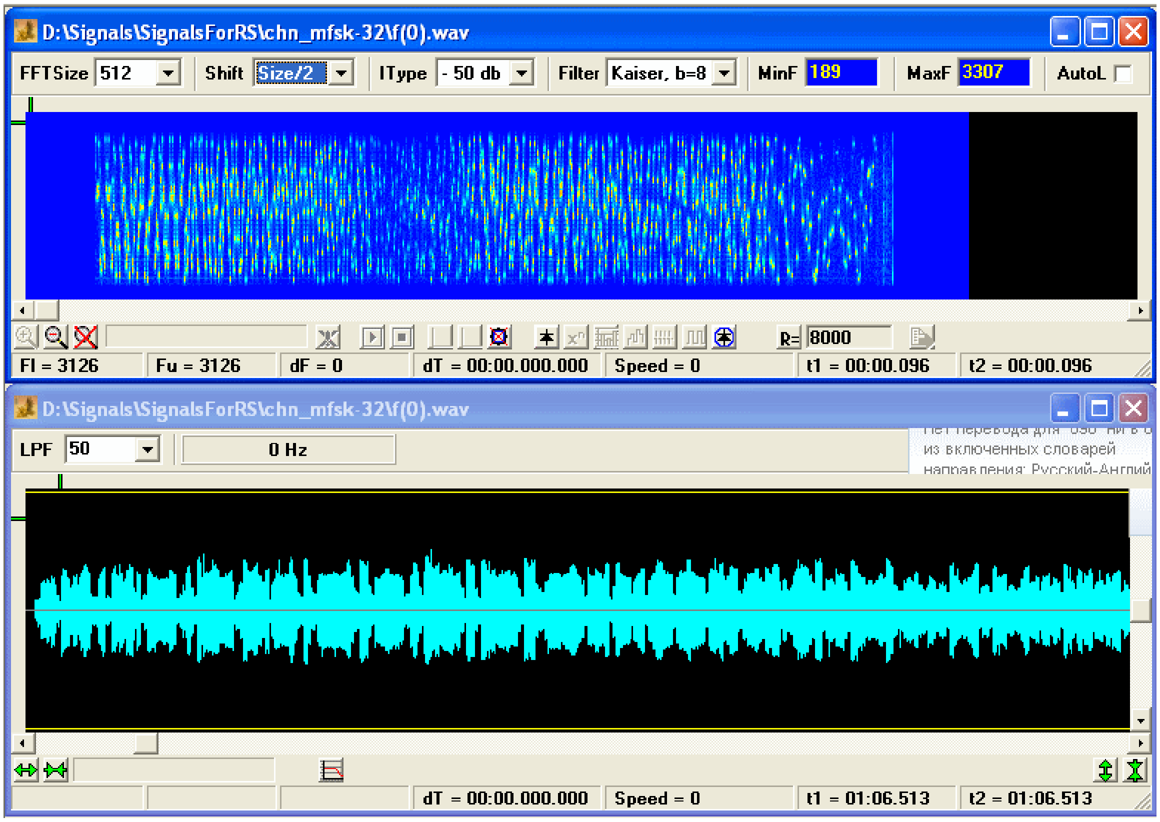
In the further examples above

1. This is a good sample with a good signal-noise ratio, but
2. is poor having a lower SNR with a very noisy spectrum background. Not suitable for analysis.

Likewise in this 32-tone MFSK the sample is poor.



Compare the above to a good sample below:



Finally, if an FSK/MFSK sample quality is poor, analysis may be possible. However if the modulation is ODFM, PSK or QAM analysis is unlikely and the file should be rejected.

The analyst can only solve with what was produced in the recorded signal. The provider must tender a recording "as is", without any additional manipulation.

19.11.2.2 Level Adjustment.

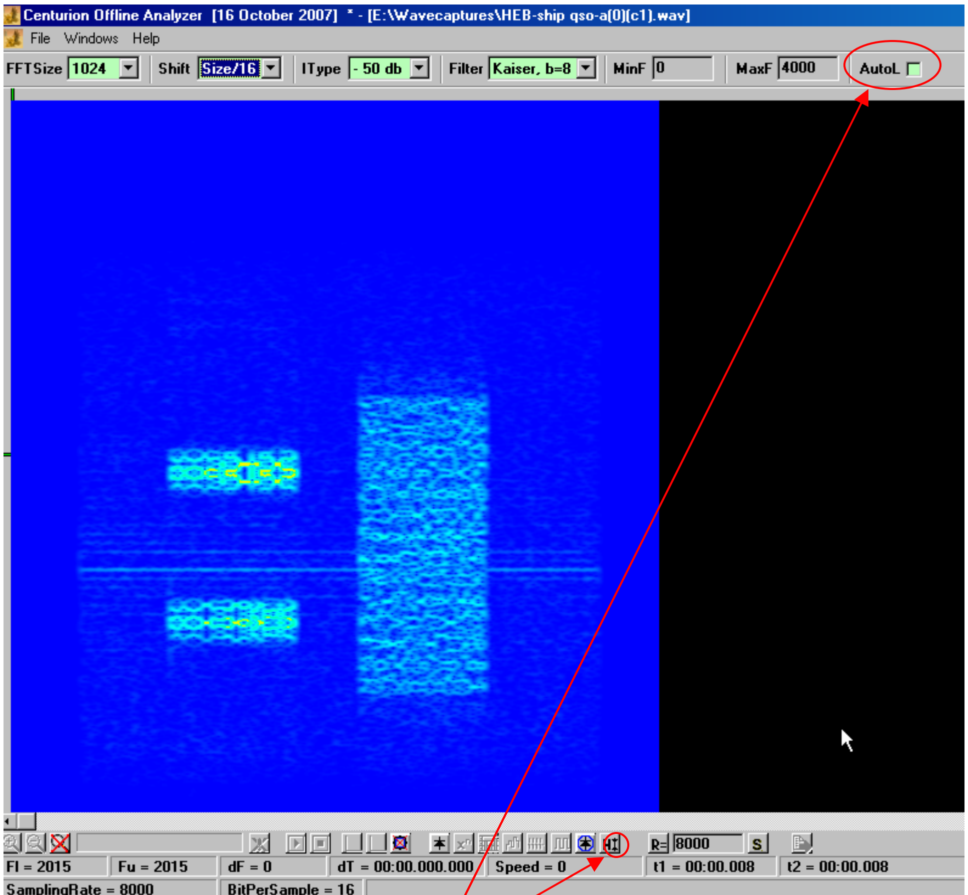
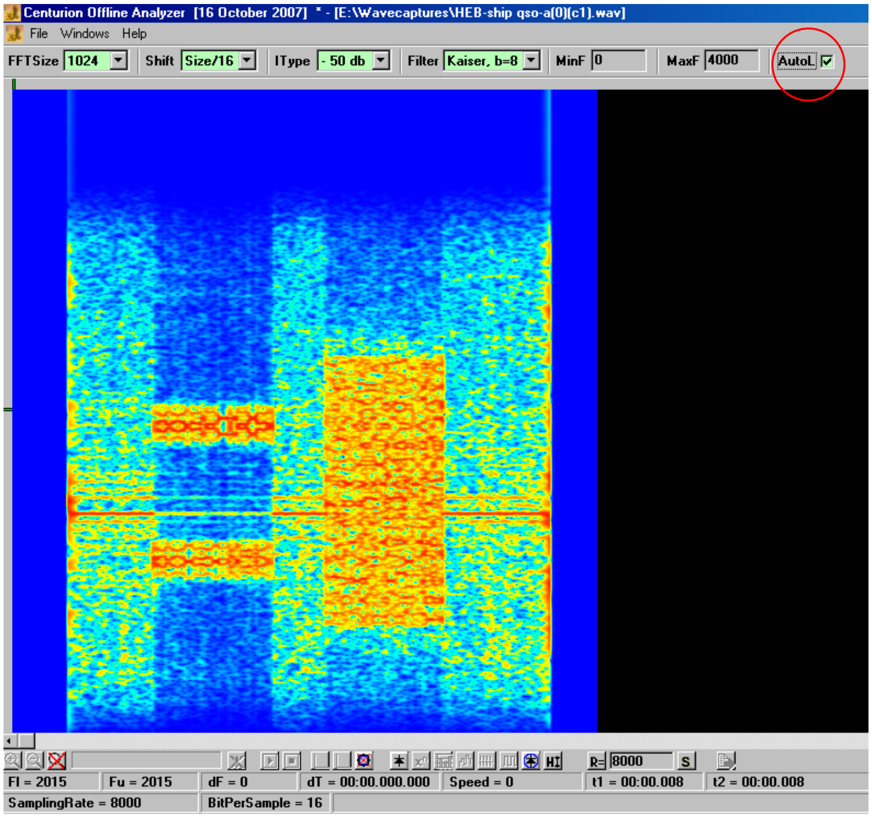


Image shows two submode bursts from a Pactor-III transmission as loaded from a pre-recorded file.

Whilst there are two level control facilities provided the analyst should really only use these for initial examination of the signal rather than use during the signal preparation phase.

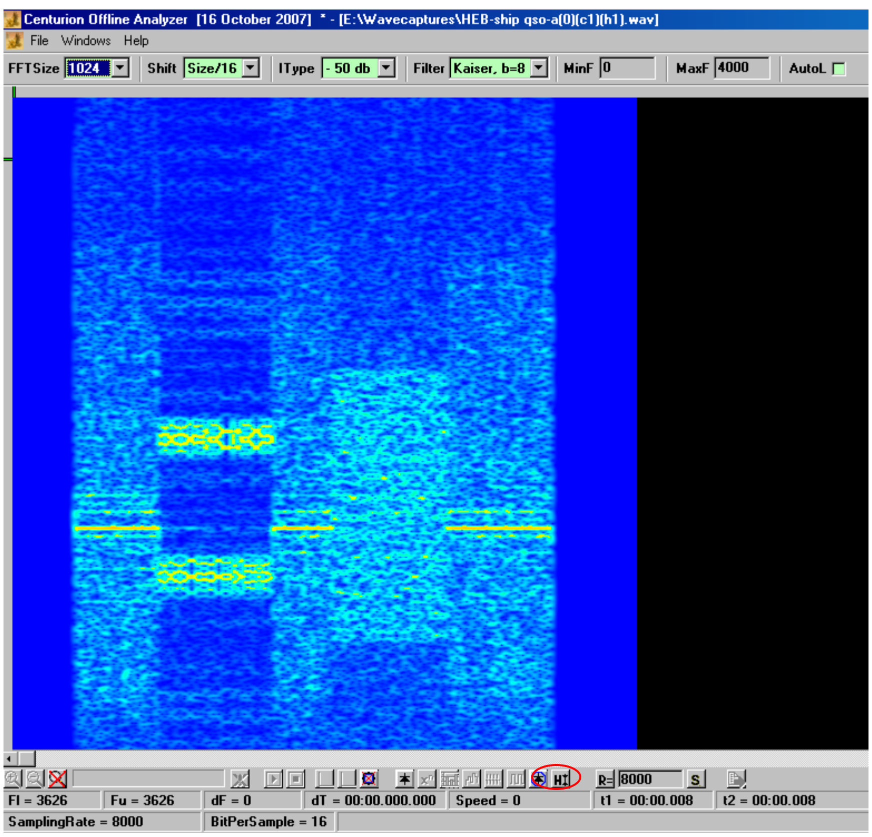
Both these functions cause distortion to the signal or the image.

These are used to compensate for poor recordings. It cannot be over-emphasized about the need to start with a good quality recording. One should turn off pre-filters, ALC and AGC during the recording stage.



Original image with AutoL (Auto Level) applied.

Changes the image but not the .WAV.

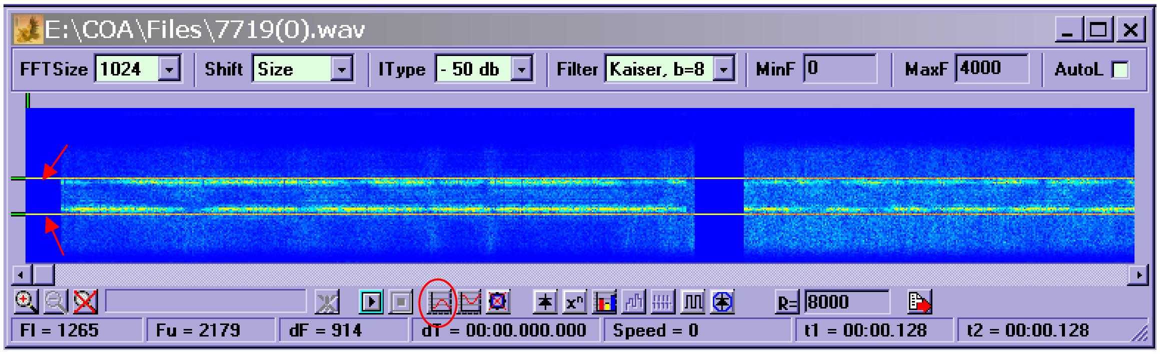


Original image with HLC (Hard Level Control) applied.

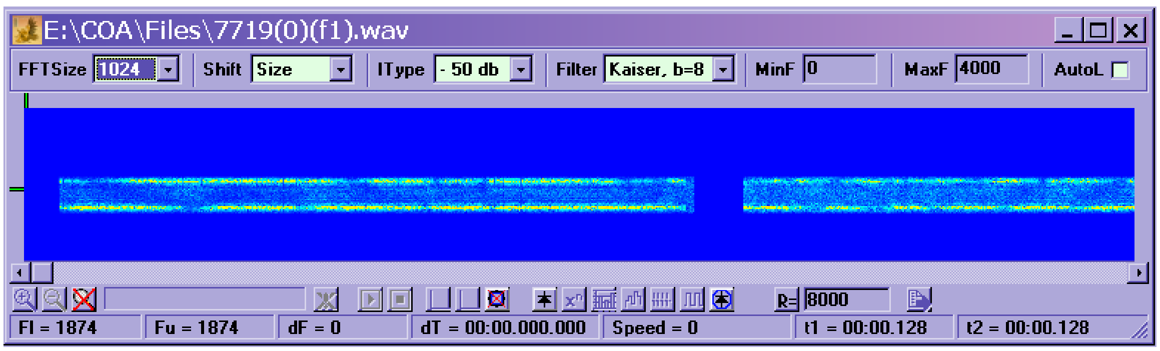
In this case the .WAV is changed.

19.11.2.3 Filtering.

For quality results all noise beyond the limits of the signals spectrum must be deleted.

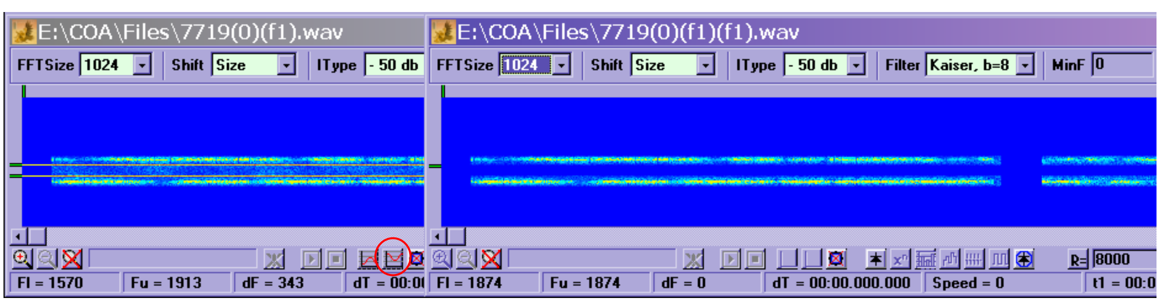


The horizontal cursors should be set approx 50-150Hz outside the signal limits and the bandpass function called.



The above result may be copied into a new file.

It may be considered prudent to use the bandstop function to remove noise from between the tones.



This should be avoided since it removes important transitional information.

19.11.3 Baud rate considerations

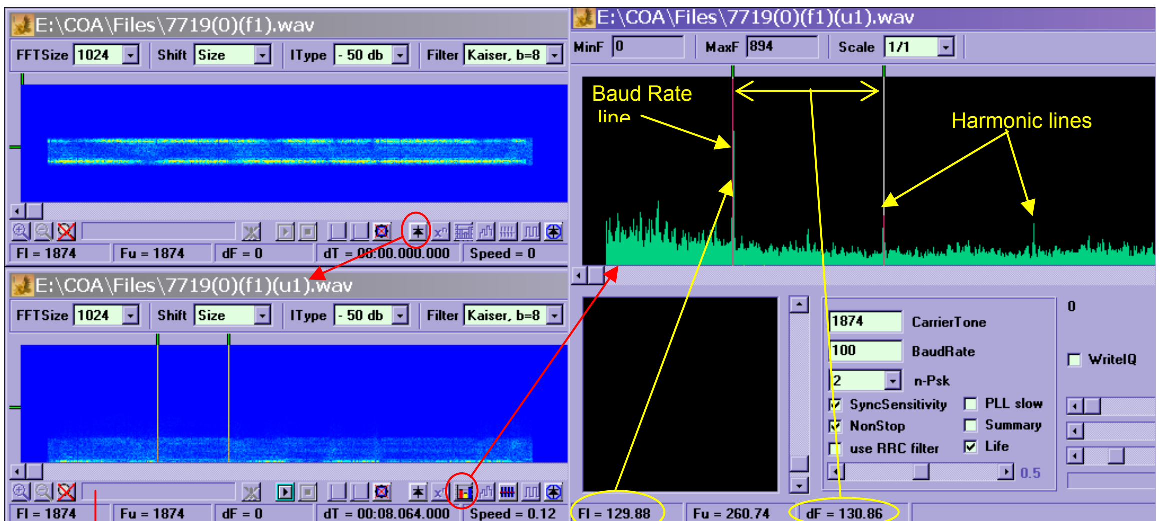
19.11.3.1 Basic measurements

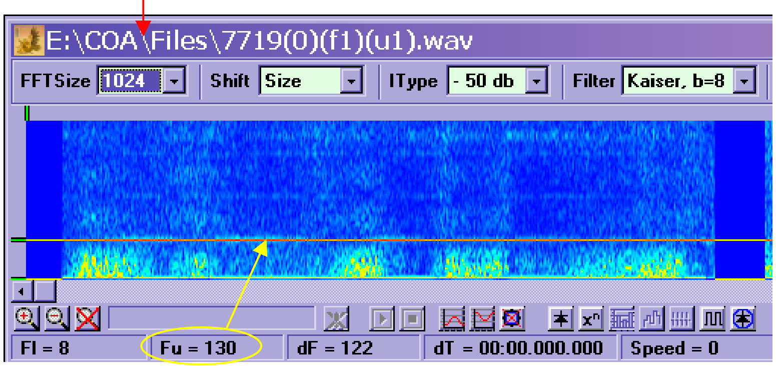
If it is required to have something measured there are two primary methods:

1. Classical method. This is the AM (amplitude detection) method. It works well on FSK, PSK and QAM signals, but is very poor, or does not work on MFSK and OFDM.

2. COA has an exclusive second method also known as Modified AM. This will work on all types of signals, but was designed specially for MFSK.

Classical

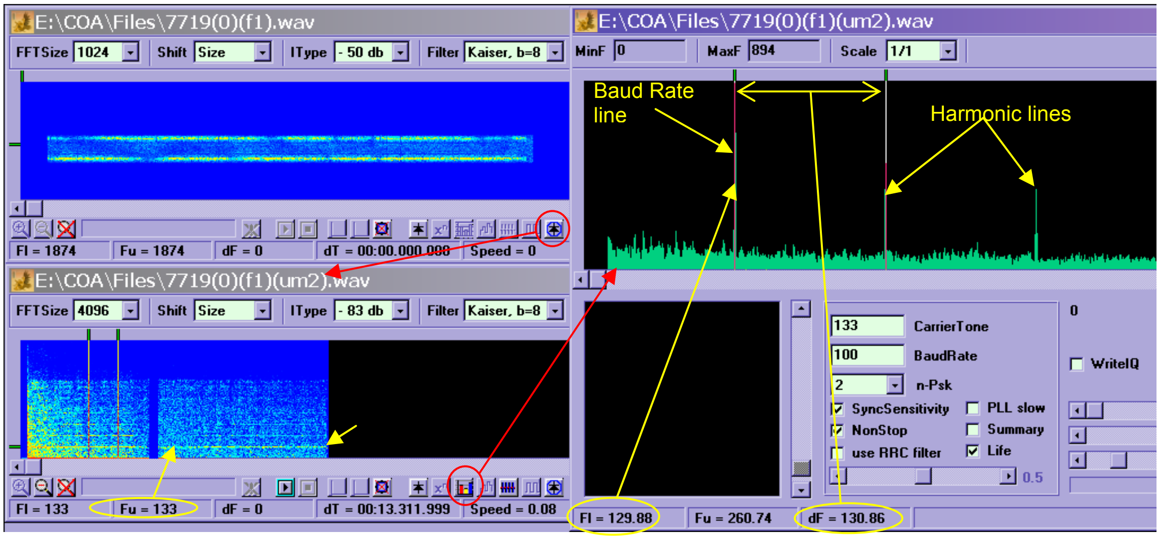




The High Resolution module is called (above) and gives a highly accurate measurement and is preferred to that obtained using the **u** spectrum window

The **u** window results can be improved by zooming as shown here. The baudrate line is measured using the Fu cursor. However this measurement is only to be considered as an estimation since one pixel represents a range of about 7-10Hz.

Modified AM



Again the **um** window results can be improved as shown (this time by adjusting FFTSize, and IType). The baudrate line (marked by the yellow arrow) is measured using a horizontal Fu cursor. As above this measurement is only to be considered as an estimation since one pixel represents a range of about 7-10Hz.

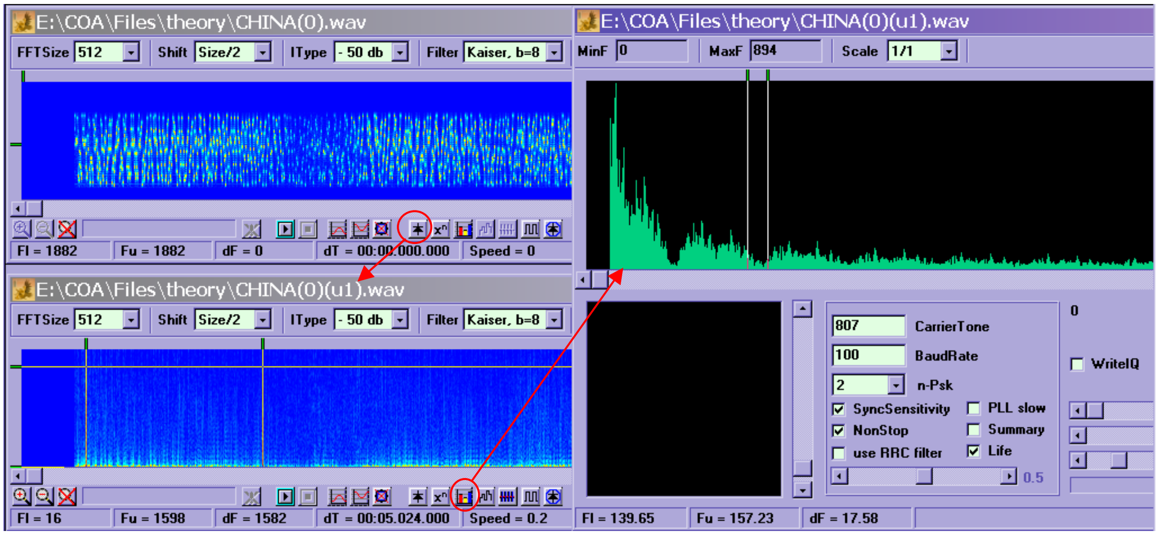
Again the baudrate is accurately measured at 130 Hz.

The Modified AM (compared to the Classical) method tends to give clearer lines and smaller noise. However the Modified AM method is not a full replacement for the Classical AM method - it is simply another instrument.

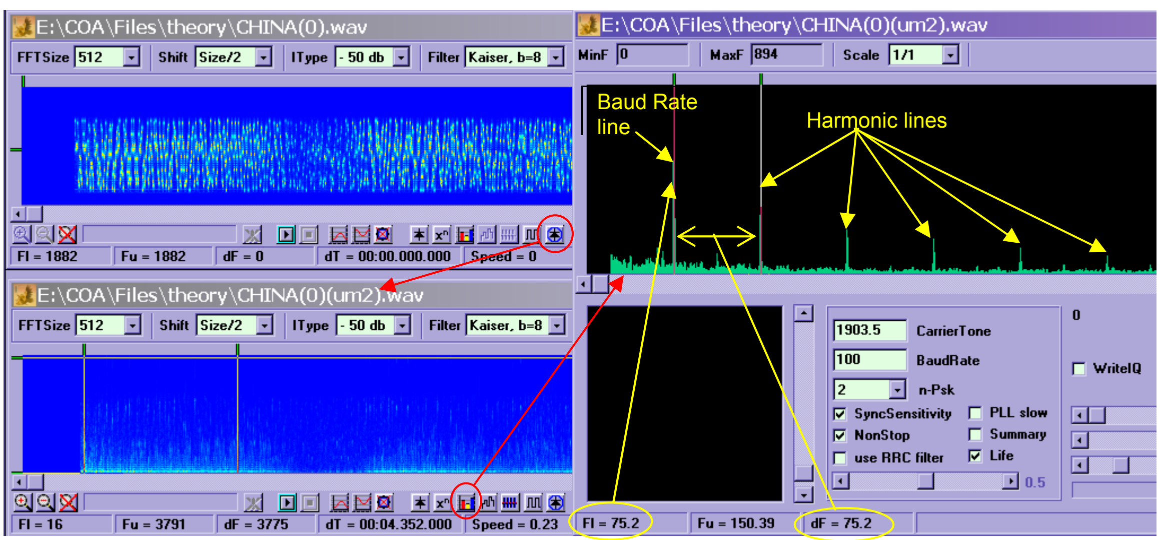
In respect of both if the signal in the High Resolution module does tend to be noisy return to the **u** or **um** window in use and try by defining with the vertical markers a better area and/or possibly a shorter section.

19.11.3.2 MFSK(1)

Classical AM method does not work on MFSK. Note the lack of spikes in the High Resolution module window.



However the Modified AM method works very well on this signal.



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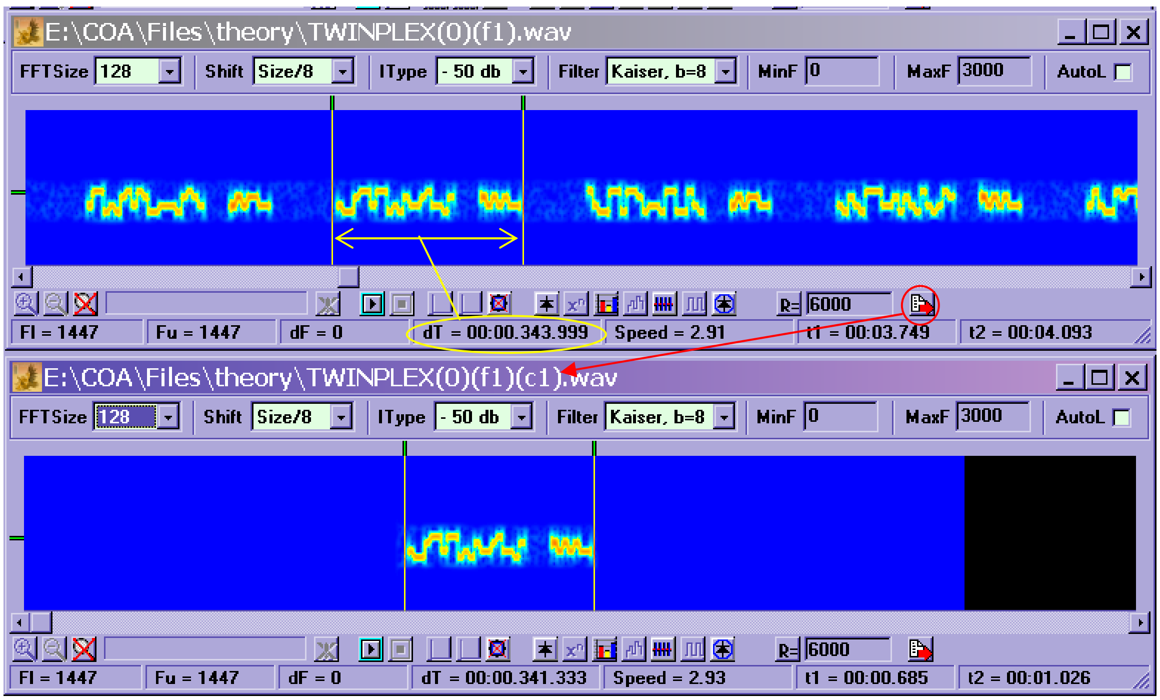
19.11.3.3 MFSK(2) - on very short bursts using direct measurement

The Classical and Modified AM functions are precise methods and must be used as first procedures. However it is not always possible eg on very short signals.

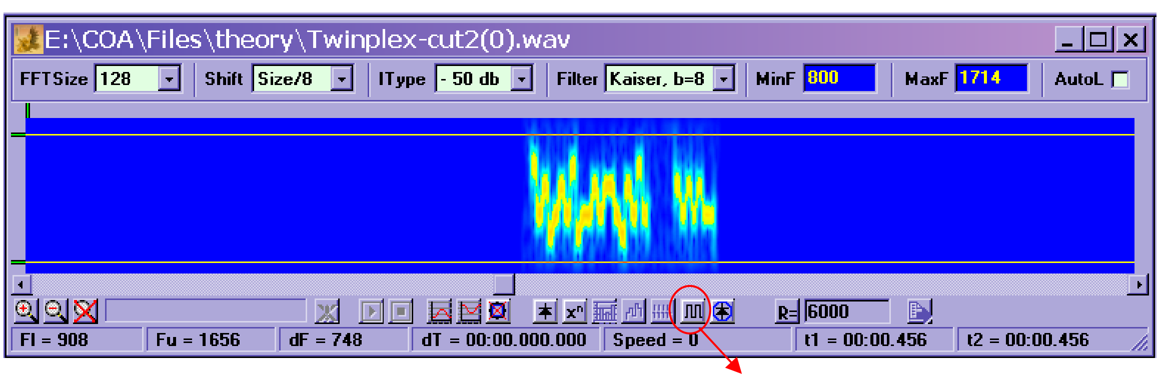
Neither the Classical nor the Modified AM methods will give good results. This is due to general problems with short and very short records.

What can be done?

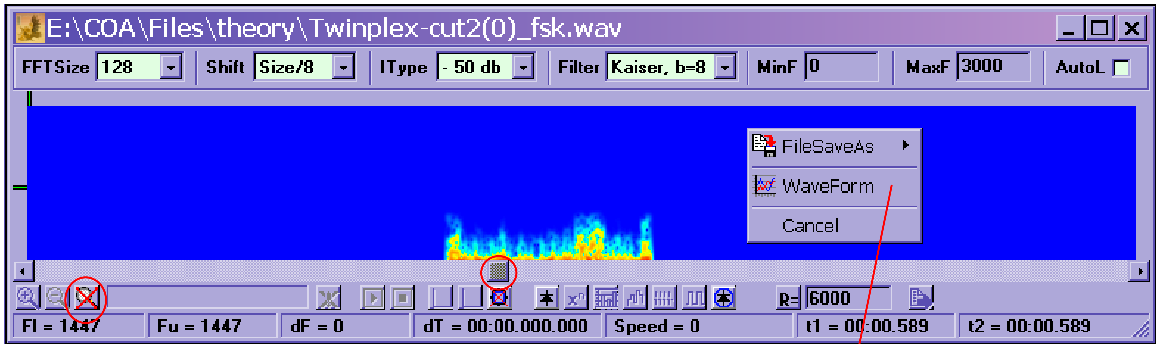
Use direct measurement; there are no alternatives. Direct measurement requires the use (for FSK and MFSK) of the FSK-DEM function.



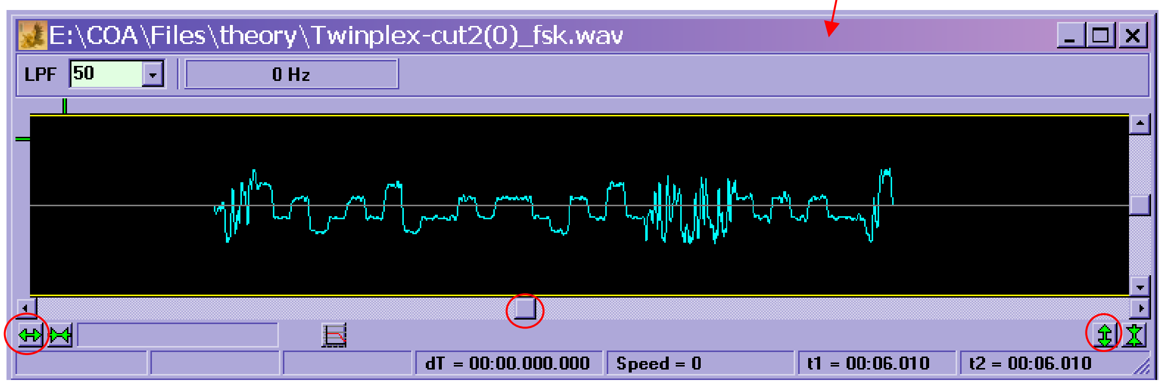
Start the exercise by filtering and creating/saving a copy of a short section of the signal.



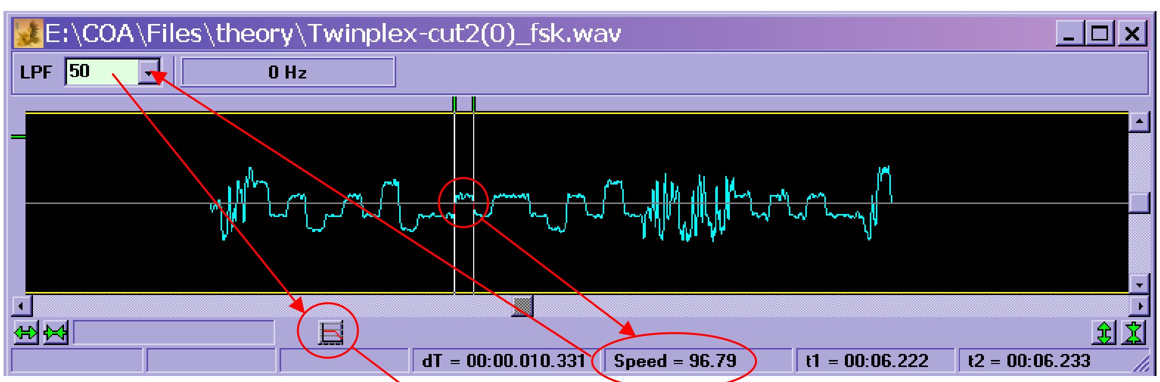
Open the new file, set the horizontal cursors and call the FSK-DEM function



If the previous window was subject to zooming click the Reset zoom button. Adjust the horizontal slider until the trace appears. Call the Waveform function.

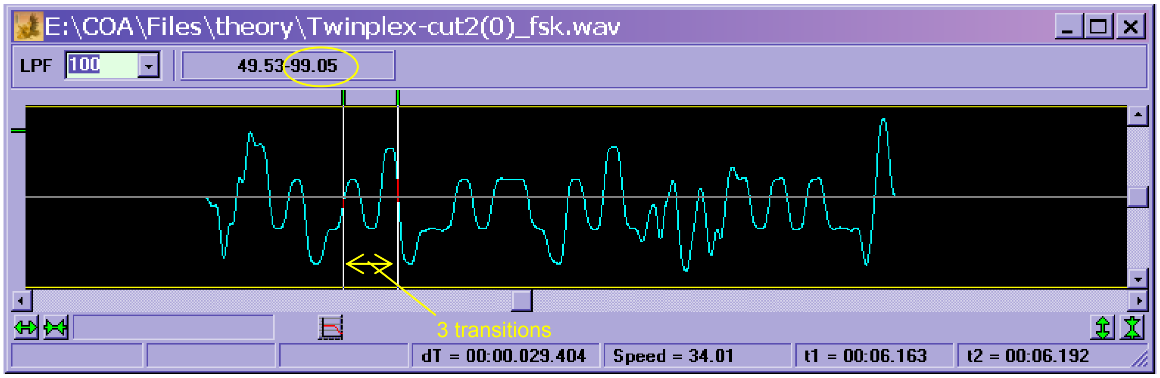


Zoom and position as required.
The next steps determine an estimated baud rate.



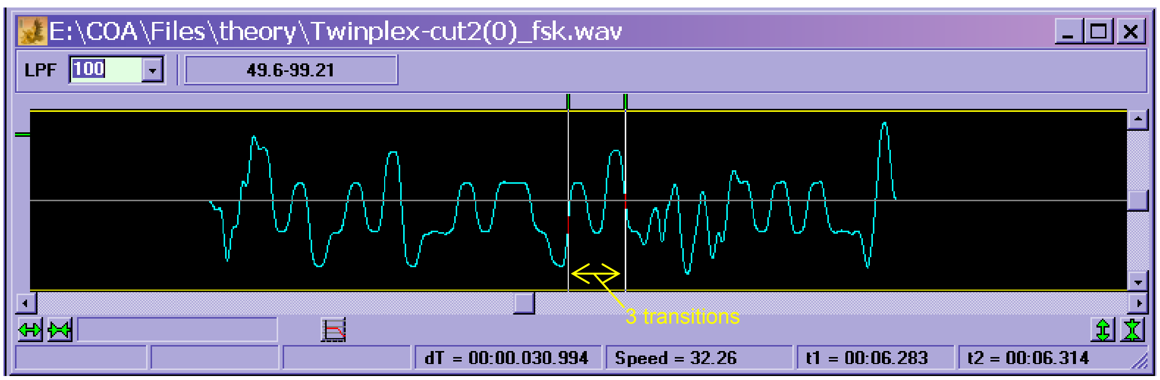
Select a short transition. The approximate baud rate appears as Speed=.
Set the LPF to this value or next greater. Invoke the update LPF function.

Waveform Viewer after LPF filtering.

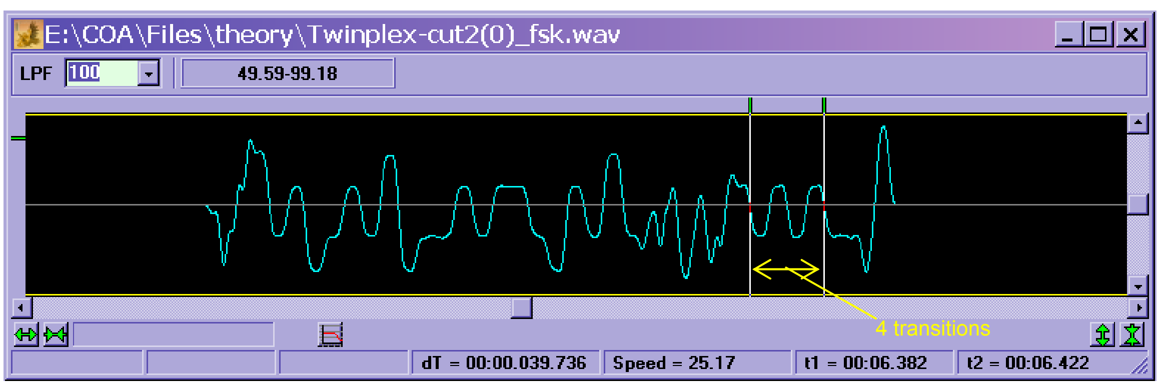


Find a section of continuous short transitions and select with vertical markers. For maximum accuracy the selection must contain 3, 4, 5,.... transitions; the more the better. There are two ways of obtaining the actual baudrate value.

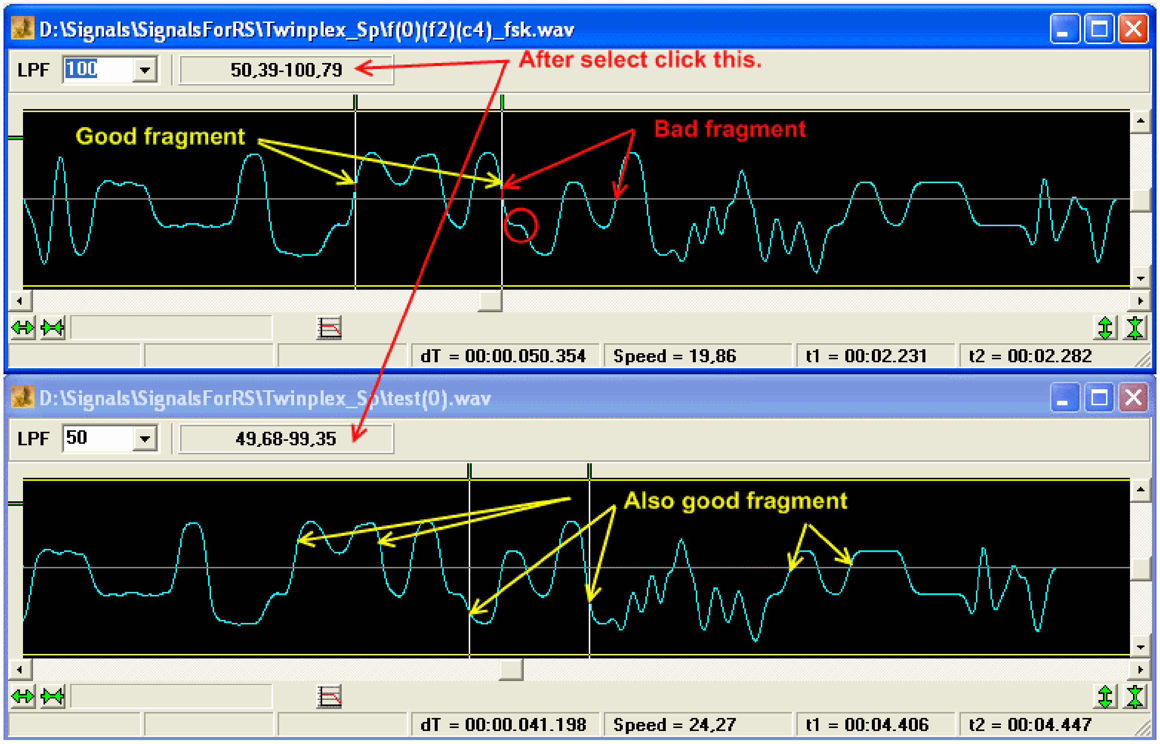
1. Click the indicated box and note the second value, or.

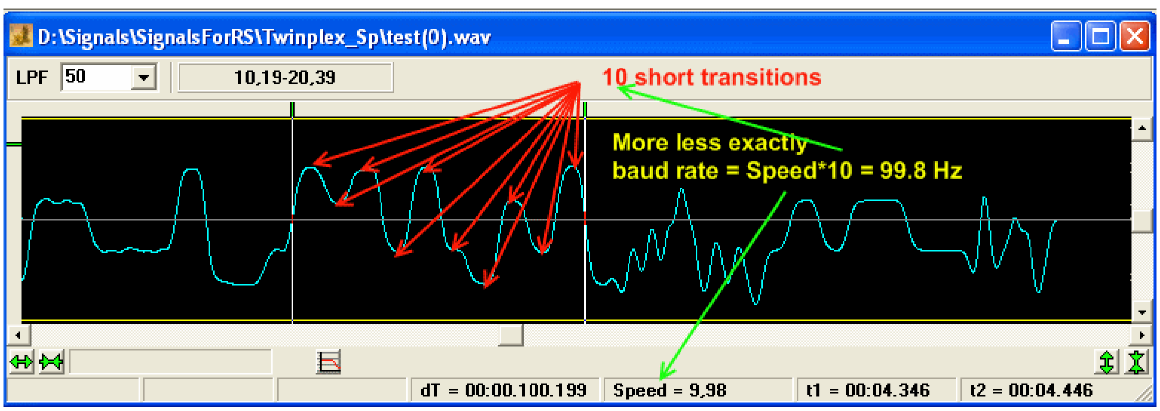


2. Multiple the Speed= value by the number of delineated transitions.



Further examples:

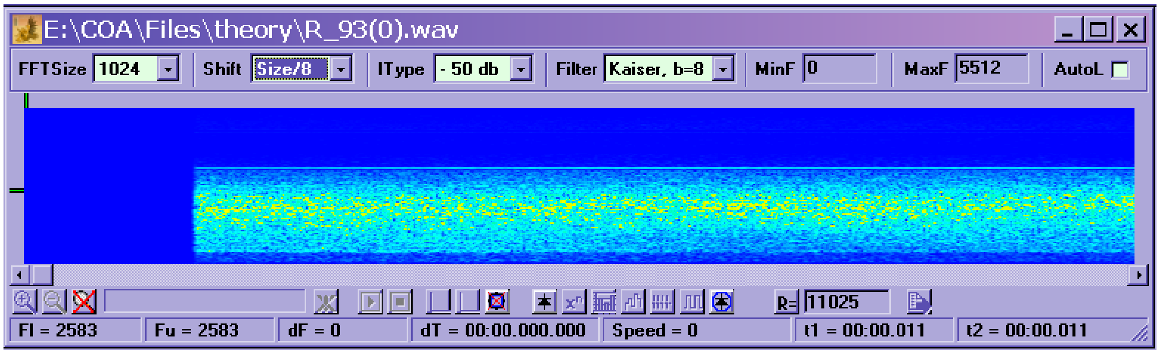


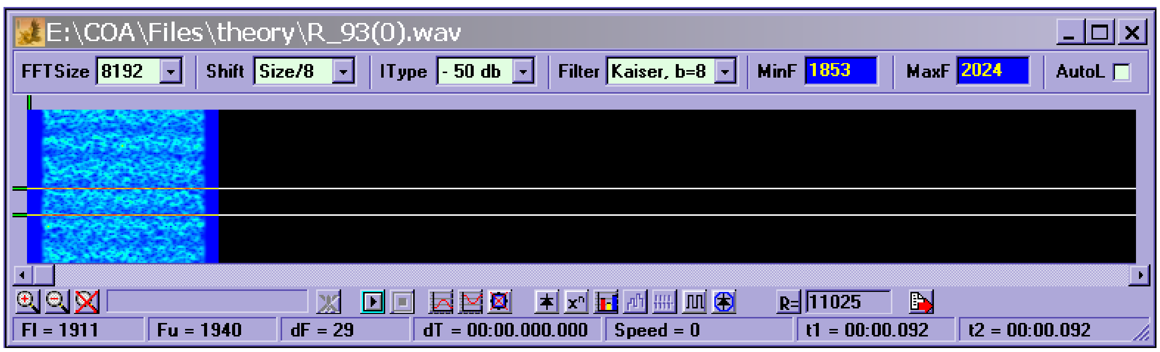


MONTERIA

19.11.3.4 OFDM(1)

OFDM is a very problematical signal particularly if of short duration. Quality of the sample must be of prime consideration for analysis. This sample has 93 tones.



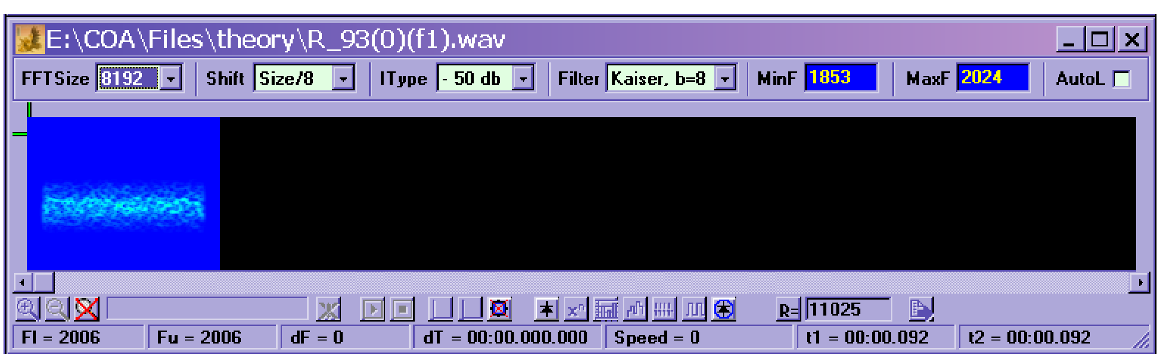


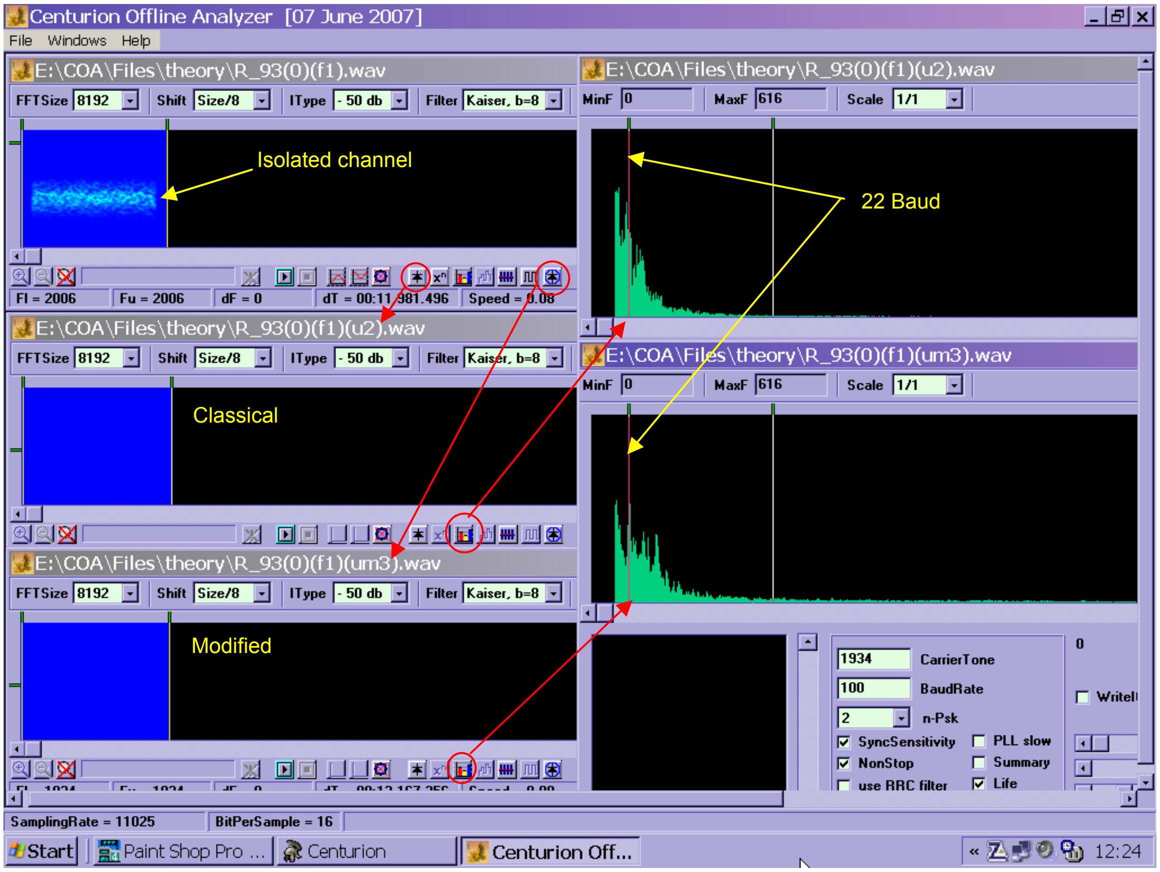
On a good quality signal by a combination of zooming, and adjustment of the FFTSize and Shift options the channels can be made discernable

The best approach is normally to select one (bottom or top) channel and determine the baudrate. The baud rate is constant for all channels.

Why bottom or top? Effect from other channels will be at a minimum.

However in this case one of the center channels is of better quality and is filtered.





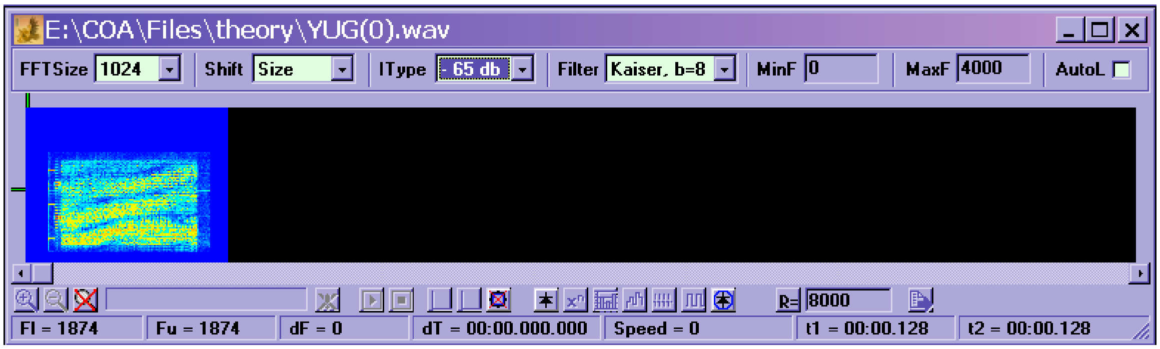
Both methods (Classical and Modified AM) are employed for accuracy and comparison. These are called in turn from the isolated channel window.

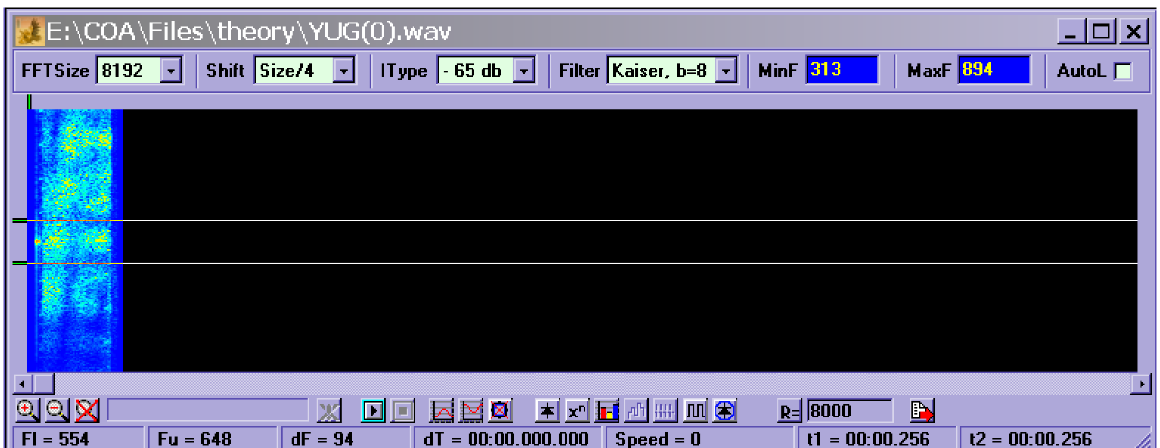
The High Resolution Viewer is called in turn from the created **u** and **um** windows.

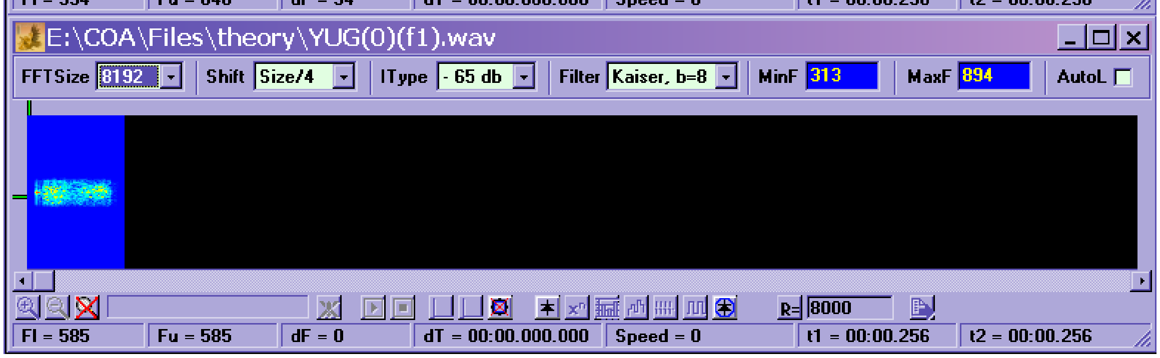
Both are seen to give the same result.

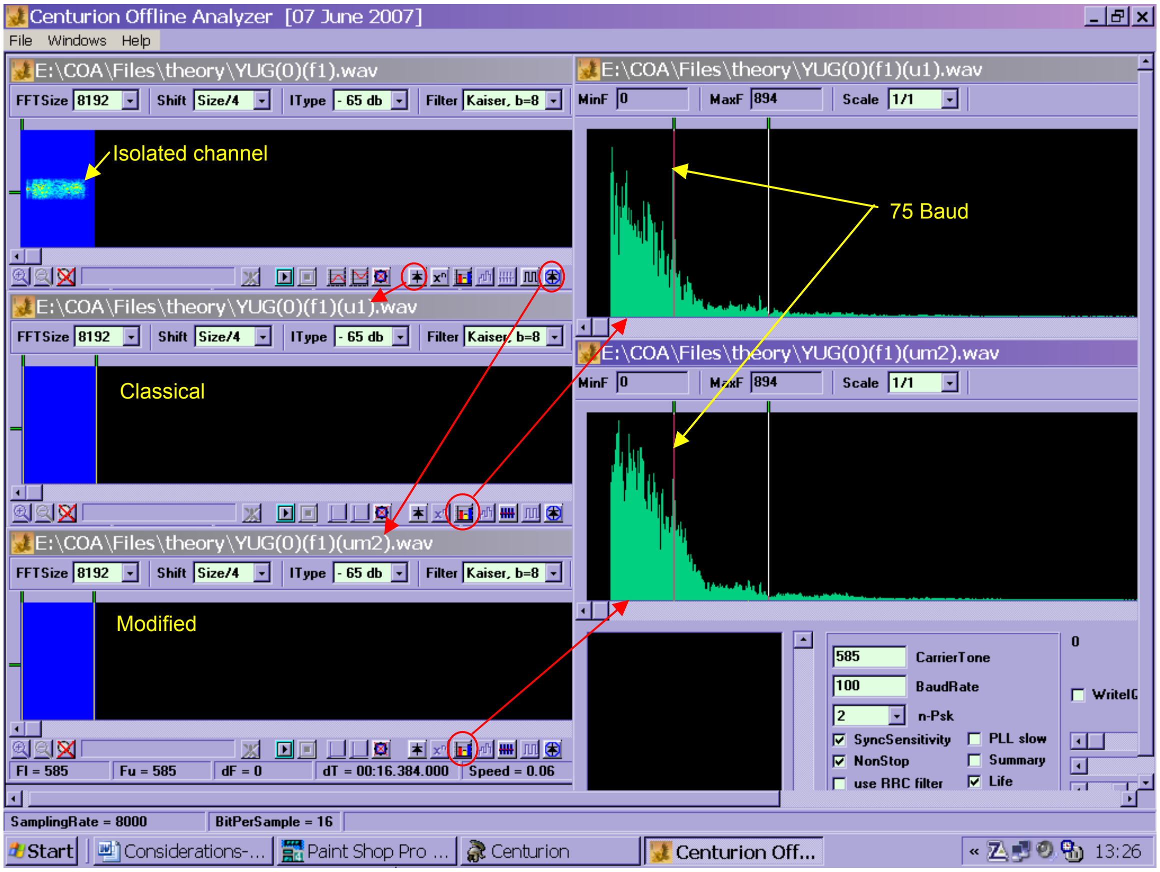
19.11.3.5 OFDM(2)

A second example using a 20 tone system as source.





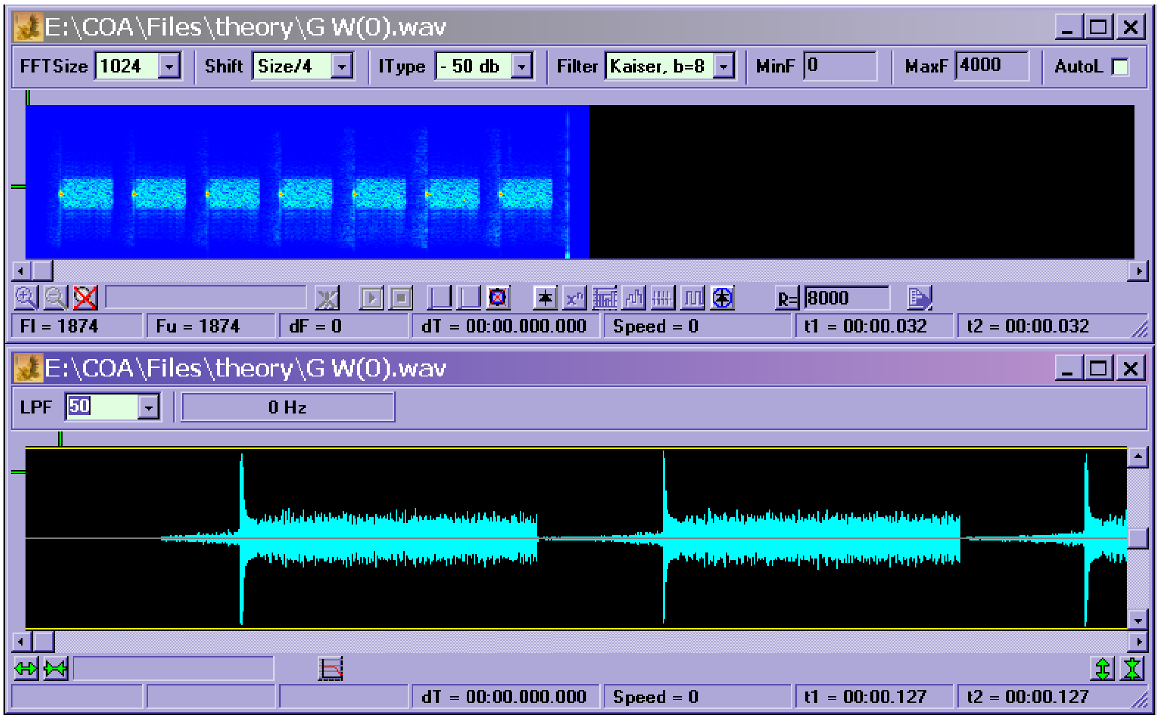




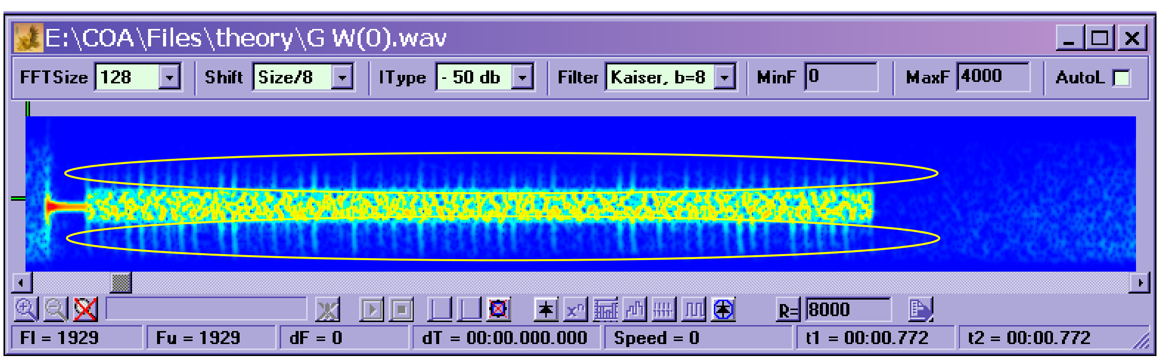
Again a very good determination of the baud rate.

19.11.3.6 OFDM(3) where unable to isolate a single channel

Now to consider the situation where the selection of one channel cannot be achieved.



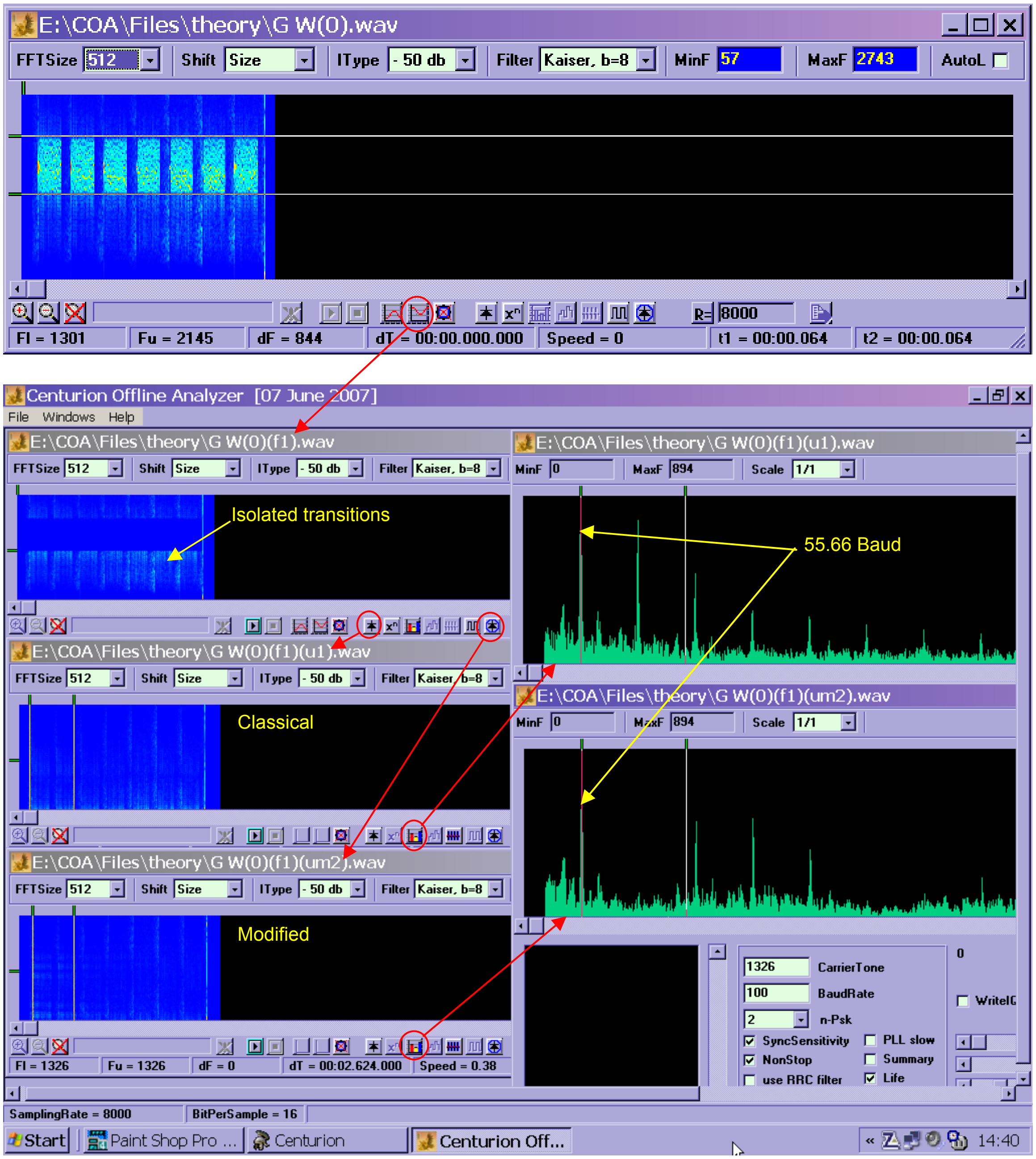
This is a good sample but selection of one channel isn't possible. A very short burst with moreover a very short cyclic prefix (typically used in OFDM technologies and channels are not visible. Therefore look carefully at the detailed spectrum of one of these bursts.



Note the range of transitions.

A simple measurement is required. Clear the windows and return to the source file.

Delineate (over a group of bursts) the core signal. Filter using the bandstop function leaving these transitions.



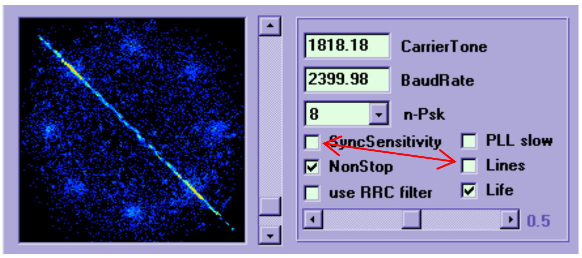
The Classical and Modified AM methods are again employed in turn to achieve a compare and accurate measurement.

As with other instruments COA has more facilities but the above are the recommendations to give an accurate result. Alternatively one could select two or three channels and use the Modify AM method. Not a guaranteed accurate procedure but is faster trick.

19.11.4 Constellation Viewer Considerations.

In the latest version of Centurion Offline Analyzer the Phase Viewer's Summary check box has been re-assigned as Lines.

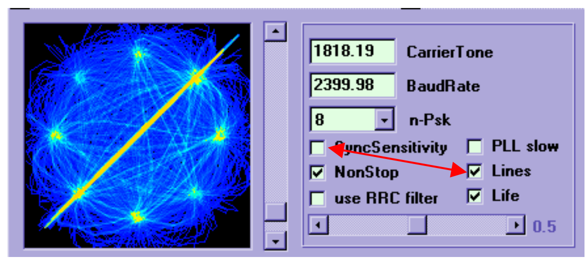
In conjunction with the SyncSensitivity setting four options can be selected to improve or give different aspects to the constellation display.

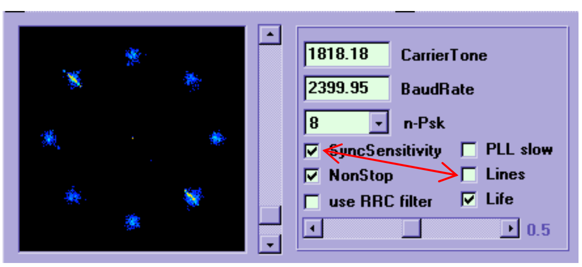


Ordinary picture. Such an image does not yield an adequate display without clock extraction, but can be useful to compare with others mode and views

Trajectory setting.

The trajectory shows the actual direction of travel from constellation point to point

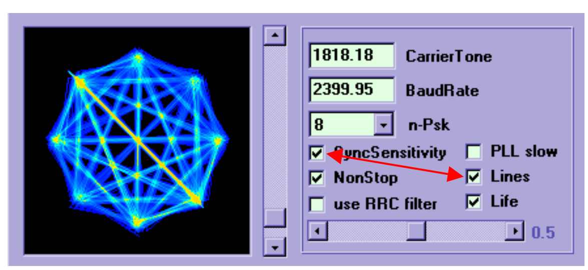




Constellation setting.

Transitions setting. This image is the default setting with both boxes checked.

The transition view shows the possible (theoretical) paths.



19.11.5 Interpreting Constellation Diagrams.

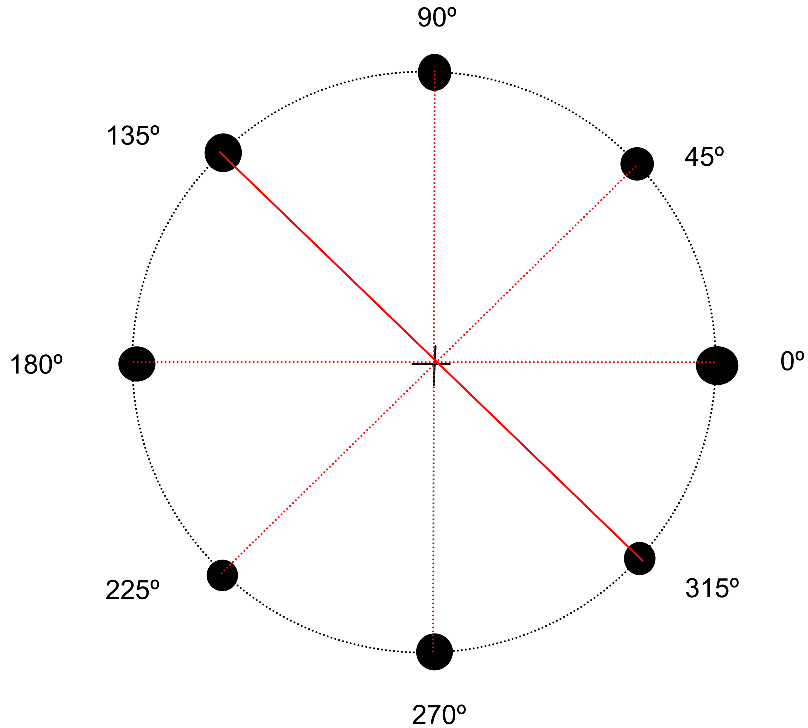
Not a definitive treatise in PSK with it's usual and frequent meanderings into calculus.

Just some basic constellation forms and how they appear in Centurion's Constellation Diagram.

19.11.5.1 The Complex Plane

In math this is a geometric representation of complex numbers established by a real axis (I) and the orthogonal (at right angles) imaginary axis (Q).

It appears in many forms and in communications as the Constellation Diagram where it provides a representation of a signal modulated under a PSK or QAM digital modulation scheme.



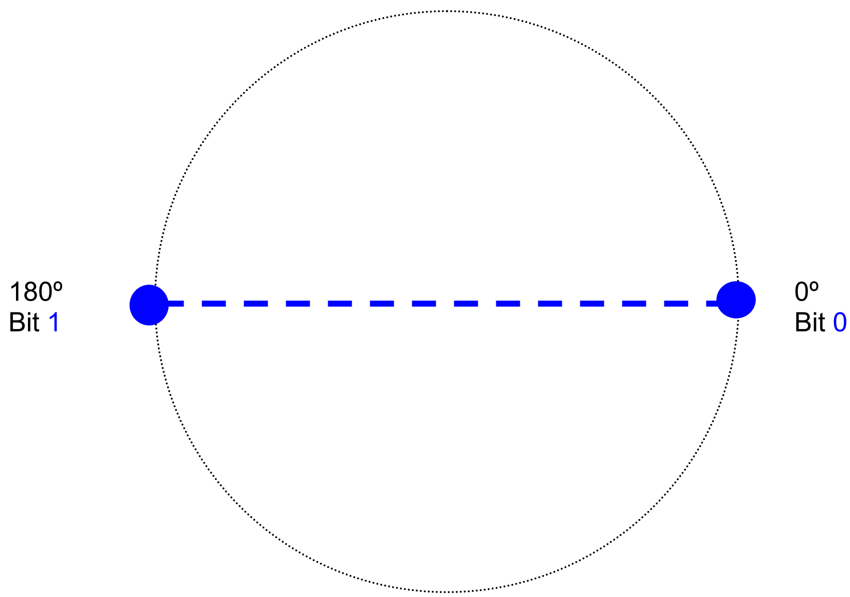
In Phase
(Real axis)

Quadrature
(Imaginary axis)

The diagram above shows the angle of each of (in this case 8) the supported phases starting at 0º and progressing anticlockwise though 360º around the origin. The Constellation diagram will show a phase, star or symbol where indicated above due to the screen persistence as the modulation holds the signal for at least one symbol period.

The dotted imaginary line represents the amplitude of the signal with reference to the origin.

19.11.5.2 BPSK

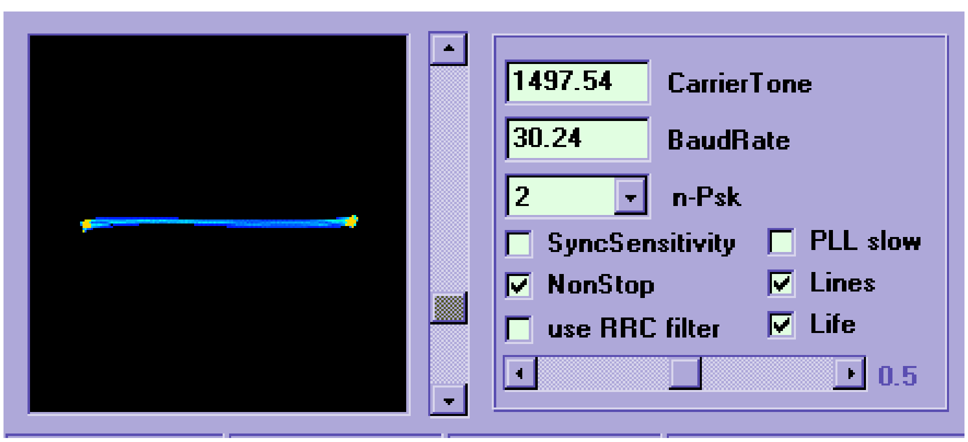


Binary PSK.

(Remember M-ary = 2^n symbol states where n = number of bits encoded per symbol.)

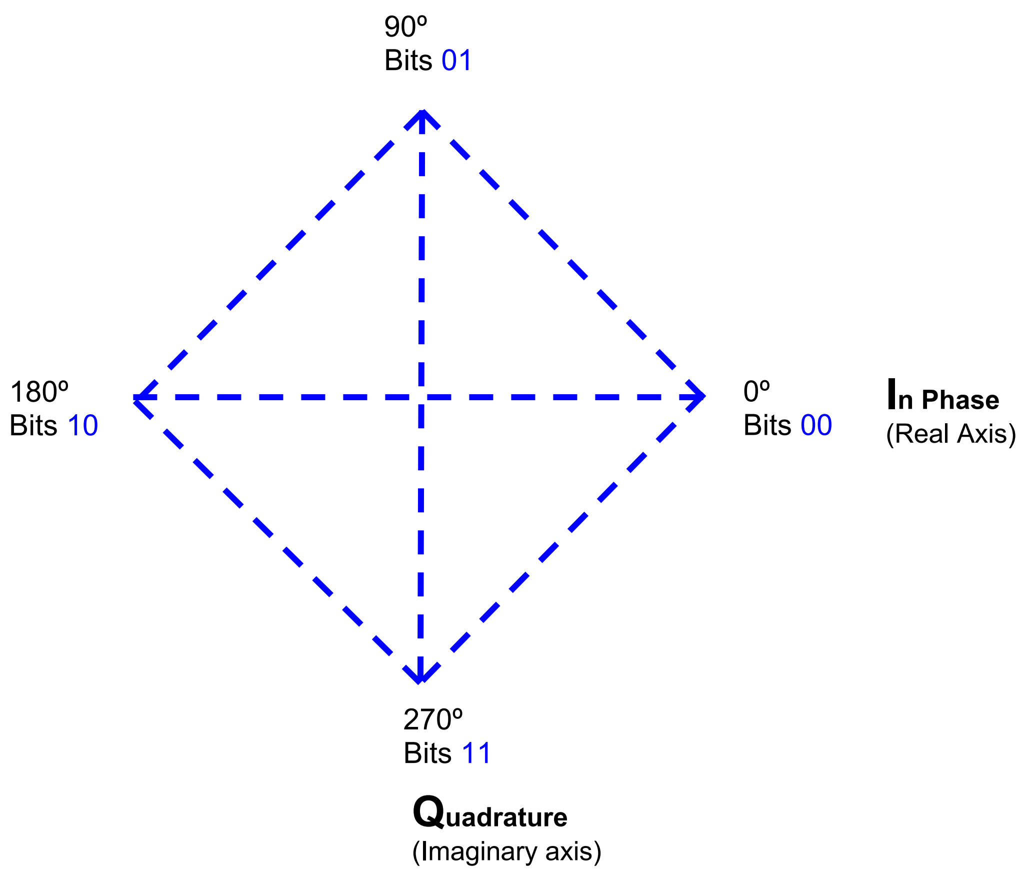
Two phases - 2-ary - each phase or symbol state represents 1 bit in the data stream.
[2^n (where n = 1)]

The dashed lines represent the transitions between one symbol state and the next.

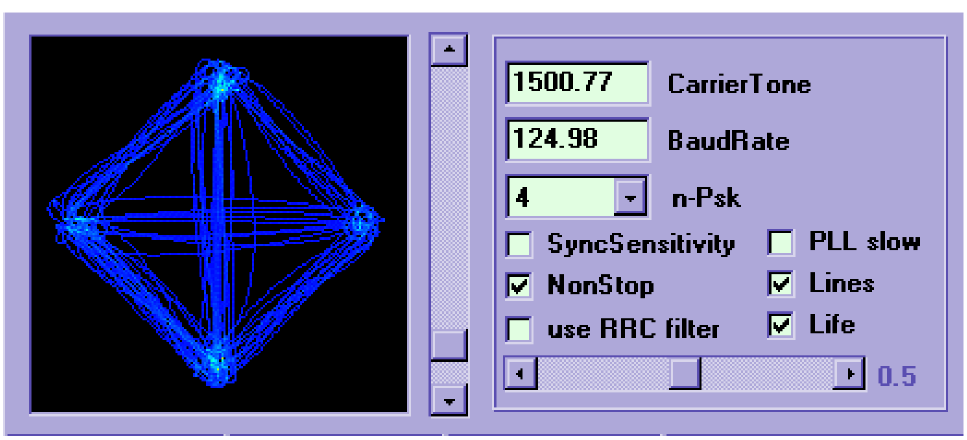


BPSK31 - 2-ary

19.11.5.3 QPSK



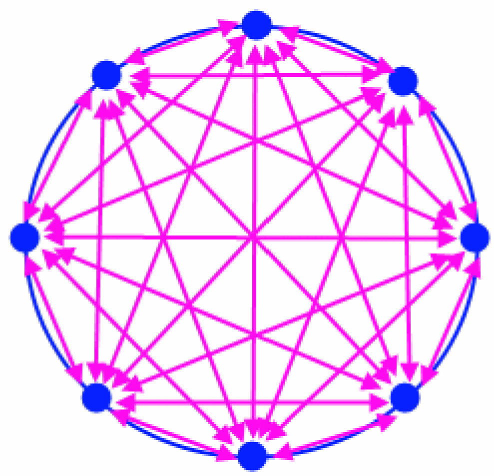
Quadrature PSK. (aka Quaternary PSK, Quadriphase PSK, or 4-PSK)
Four phases - 4-ary - each phase represents 2 bits in the data stream. [2^n (where n = 2) = 4]



A sample of how QPSK is displayed on Centurion's Constellation Diagram.
Note that in QPSK there are transitions between symbols both 90^0 and 180^0 apart

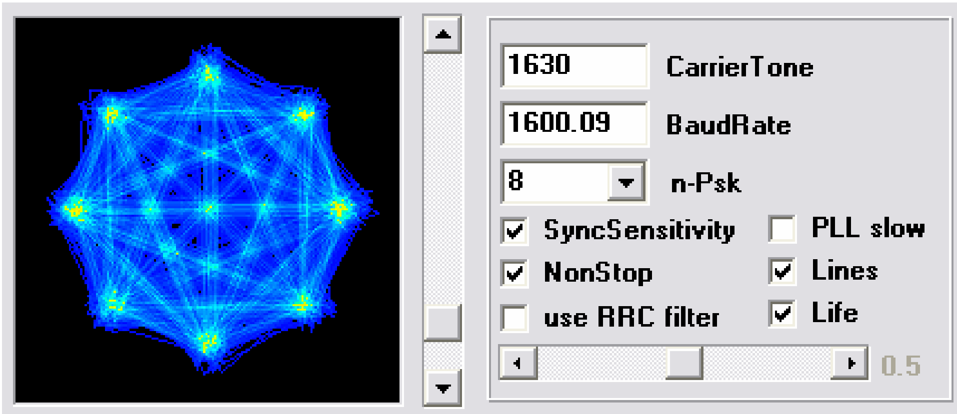
19.11.5.4 8PSK

(used in PACTOR-II, PACTOR-III, STANAG and other systems)

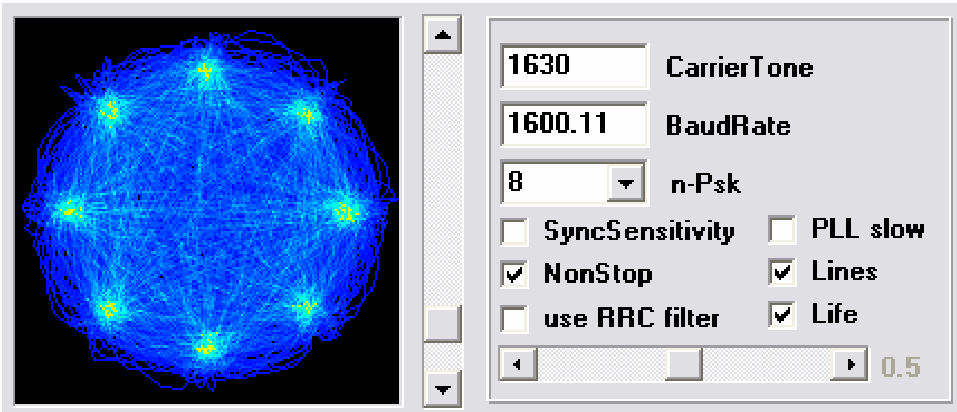


Eight phases - 8-ary - each phase represents 3 bits in the data stream. [2^n (where n = 3) = 8]

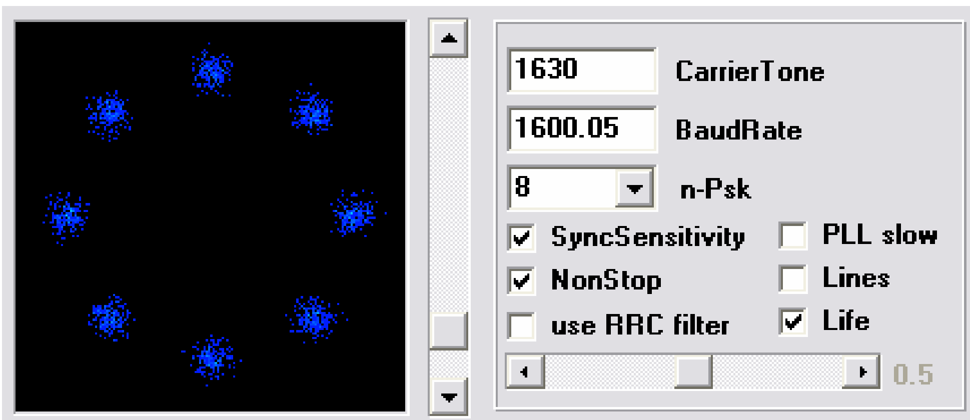
8PSK Transitions



8PSK Trajectories



8PSK Phase Constellation



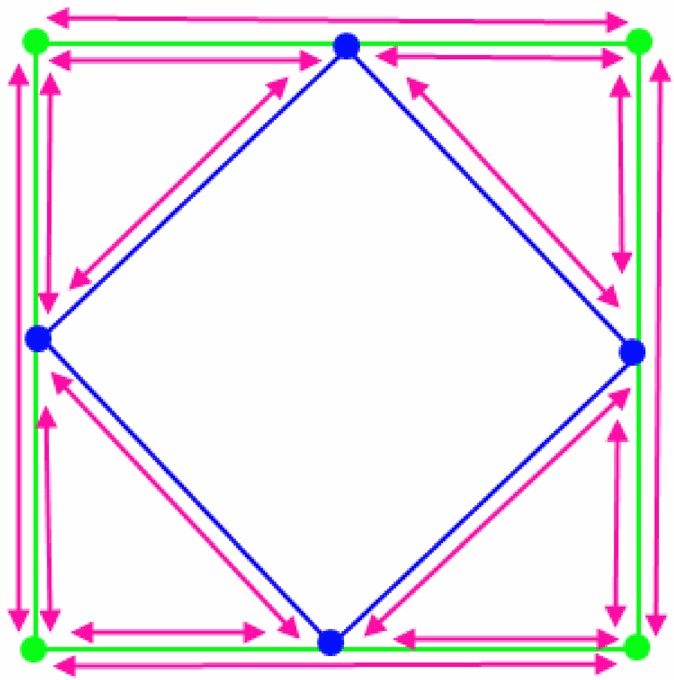
19.11.5.5 OQPSK

(Used by CIS-1280 system, CDMA and other systems)

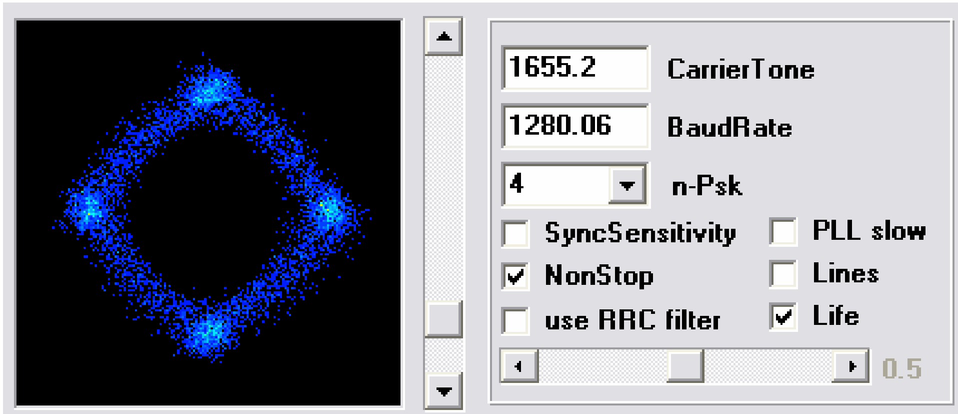
Offset QPSK. (aka Staggered PSK)

In this case the I and Q data streams (considered as alternate odd and even bits in the stream) are not permitted to change modulation states together but are offset or staggered by half a symbol. This results in no symbol transitions of 180^o occuring. The signal never passes through the origin.

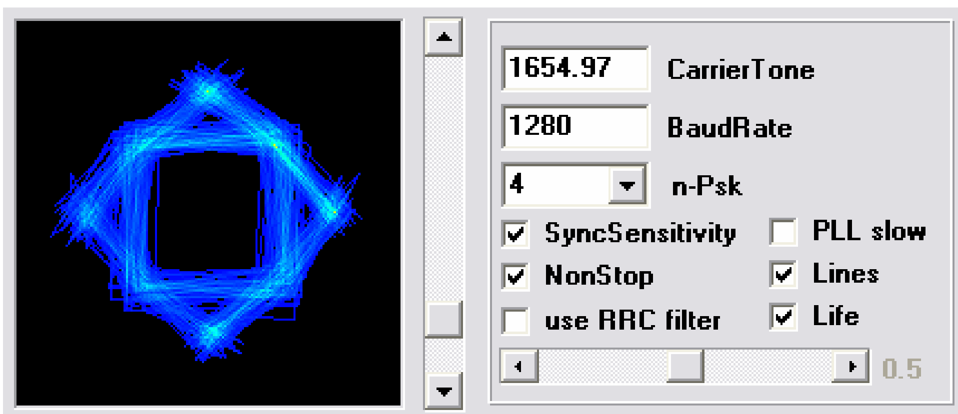
This method gives an interesting transition scheme; moreover it displays a compact spectrum and maximum speed at once. For OQPSK, bandwidth of spectrum = baud rate.



Typical picture OQPSK on ordinary phase viewers, looks like this:

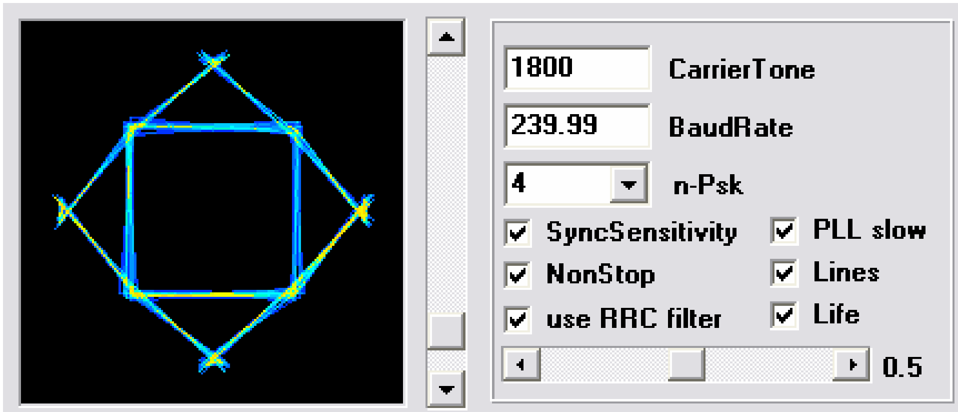


In analysis, it is desirable to view full transitions:

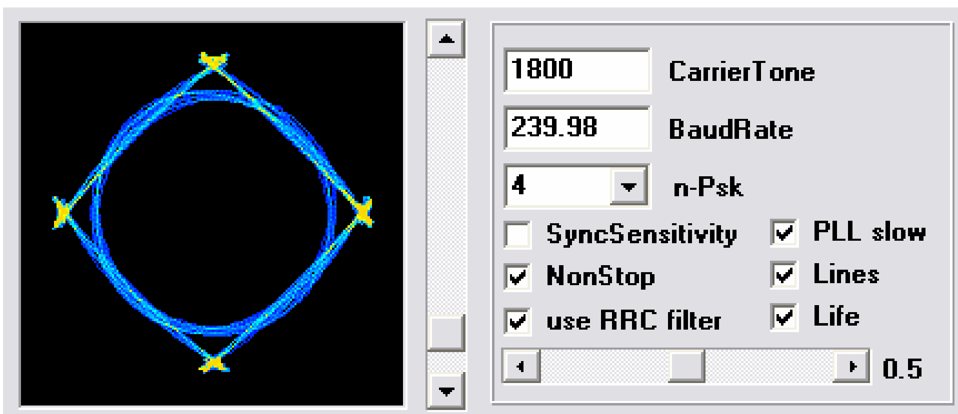


Transitions of OQPSK are theoretical, and not real trajectories. Real trajectories are better-displayed on generated signals, without noise and distortion.

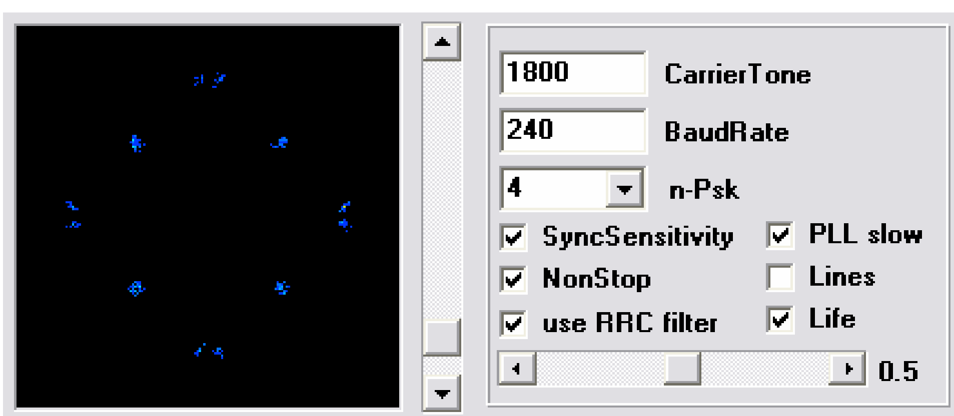
OQPSK Transitions



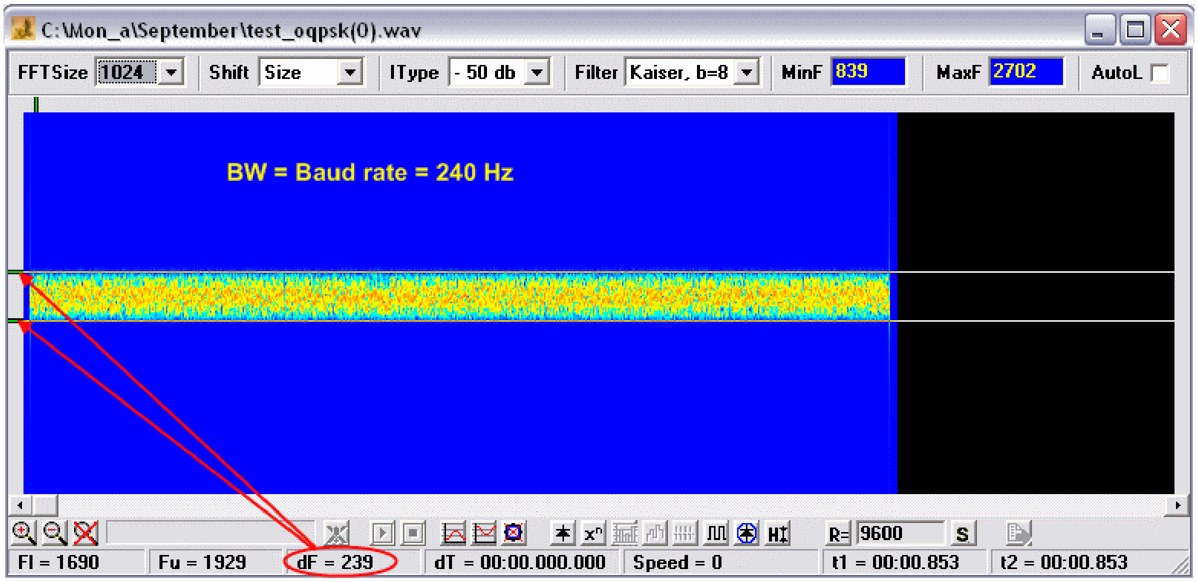
OQPSK Trajectories



OQPSK Constellation



OQPSK Spectrum

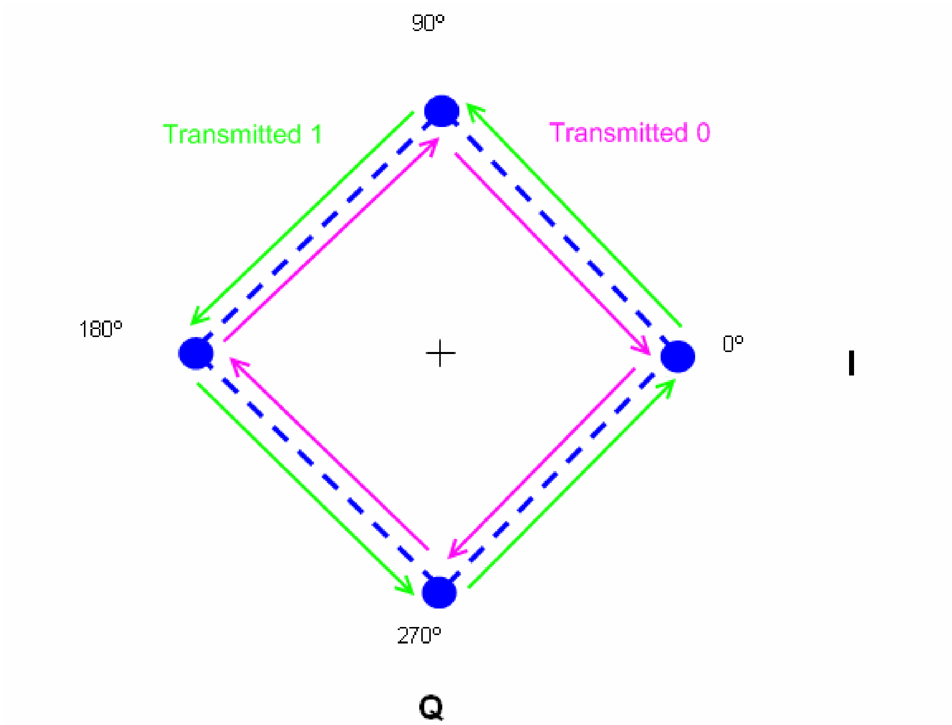


OQPSK has both advantages and disadvantages, and one difficulty is in clock extraction. Problems with clock extraction occur with BPSK, QPSK and 8PSK as well as with DBPSK, DQPSK, etc. If data has long strings 0…0 (for example) then point of phase does not move, and clock extraction is impossible. There are other phase manipulations that will allow for clock extraction.

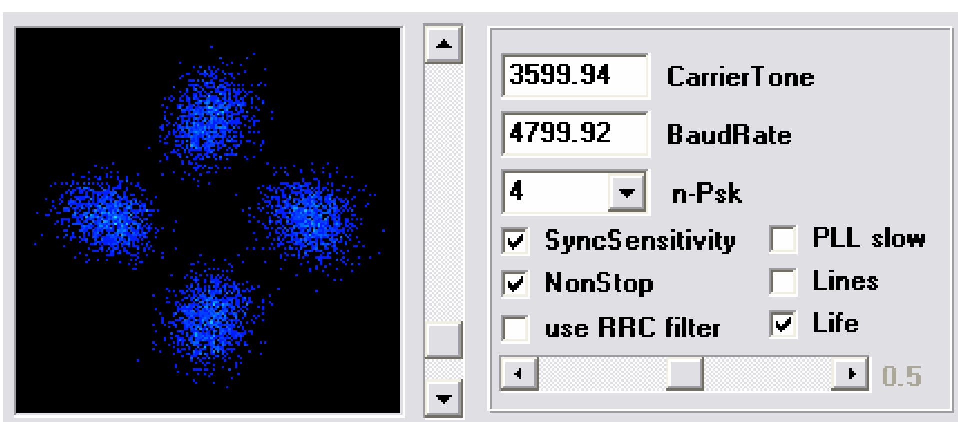
19.11.5.6 SDPSK (Staggered Differential PSK)

(Used by the ORBCOMM satellites)

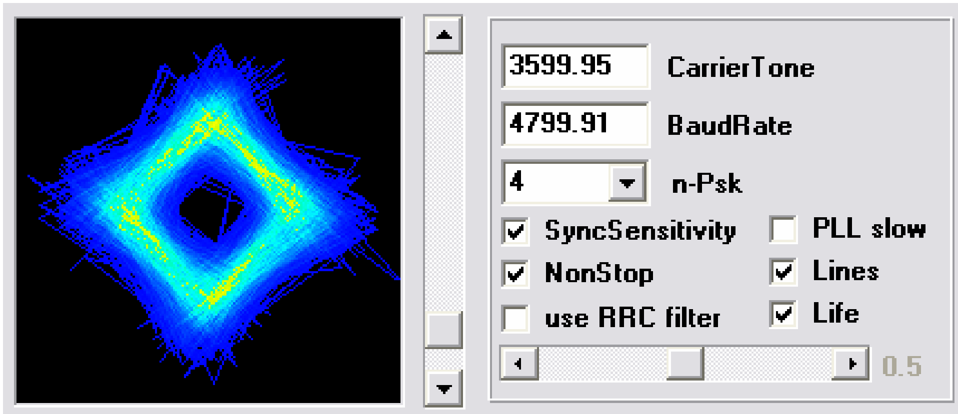
In SDPSK, each bit represents a direction of phase change, for example: +90 = 1 and -90 = 0.



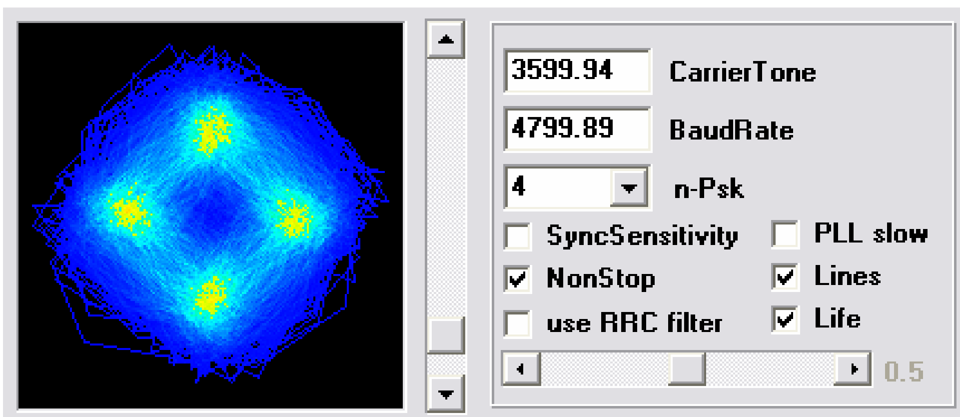
SDPSK Constellation



SDPSK Transitions



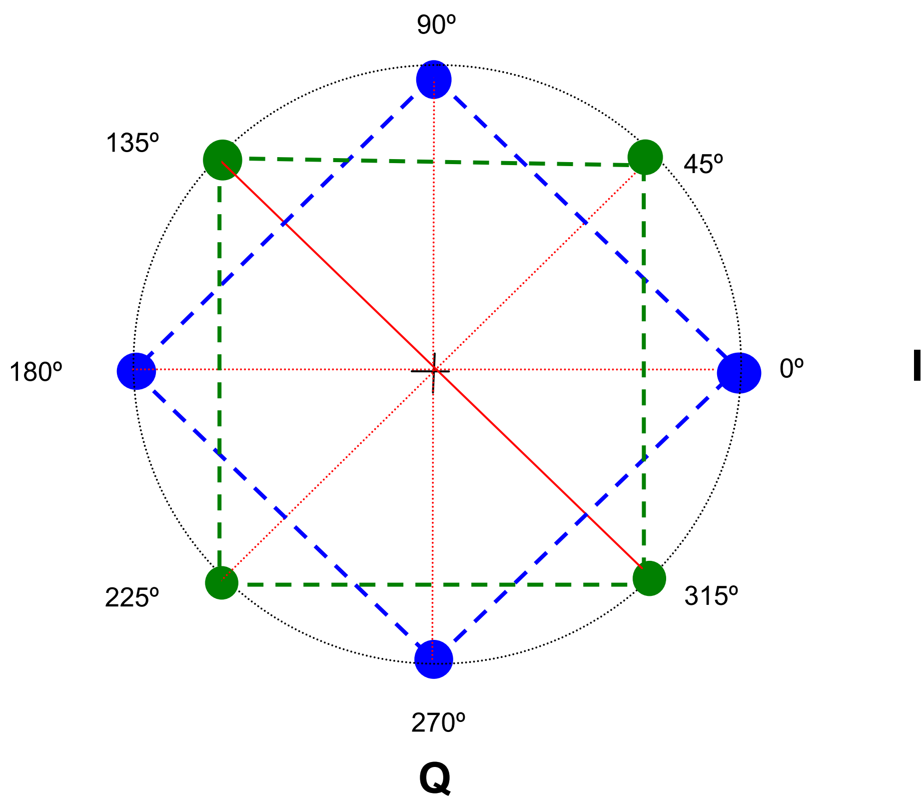
SDPSK Trajectories



19.11.5.7 π/4-DQPSK

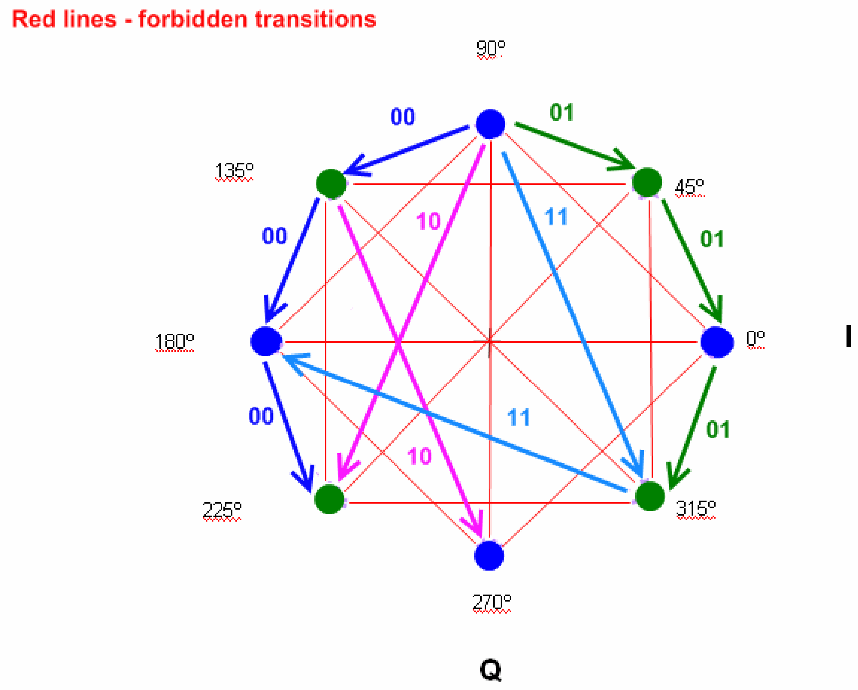
(Used in PACTOR-II, PACTOR-III and some mobile telecommunications services)

This variant uses two identical constellations which are rotated by 45° (= π/4 radians from which the name is derived).



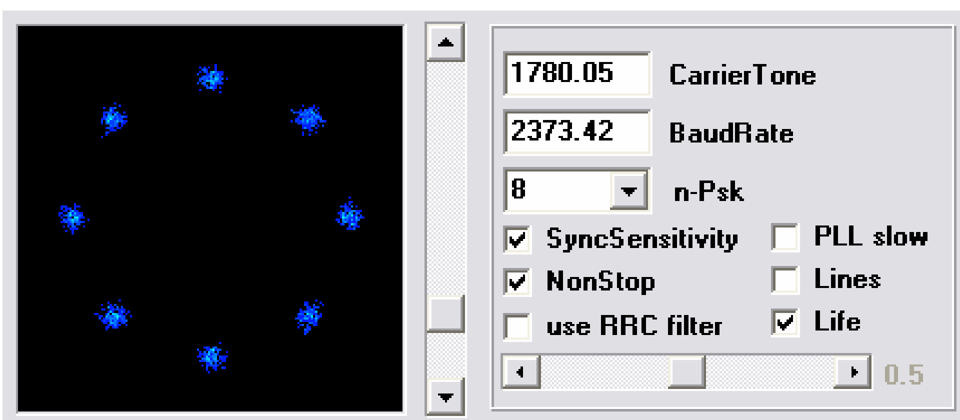
SDPSK utilizes phase change direction for transmitted data, but permits transitions only between two constellations (green↔blue), and does not allow inner transitions (green↔green, blue↔blue).

This diagram shows the composite signal modulation and transitions for pi/4 DQPSK

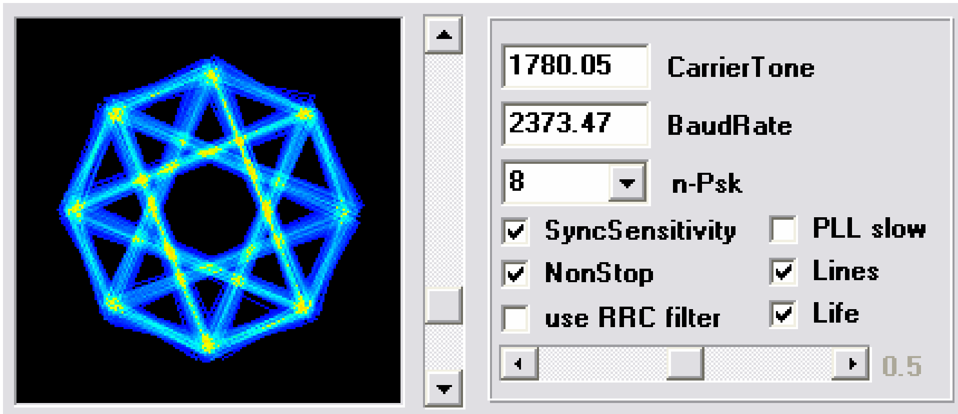


In other words, transitions on (for example) +45 = 00, -45 = 01, +135 = 10, -135 = 11. This method also, as with SDPSK, always guarantees very reliable clock extraction.

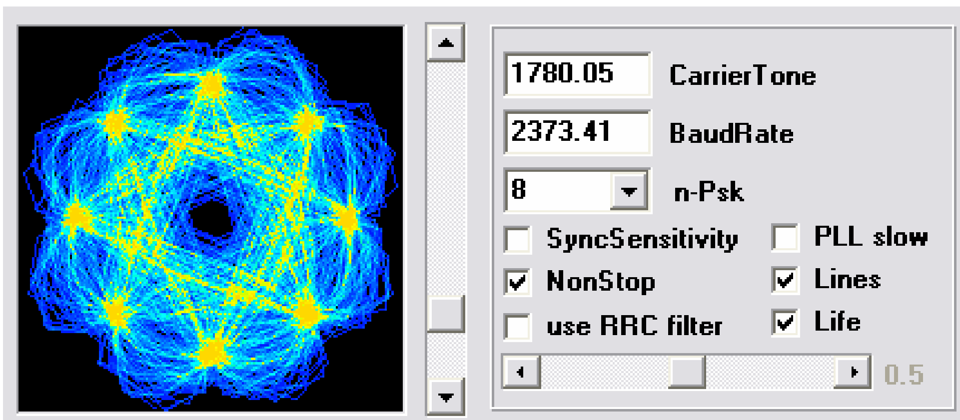
pi/4 DQPSK Phase Constellation



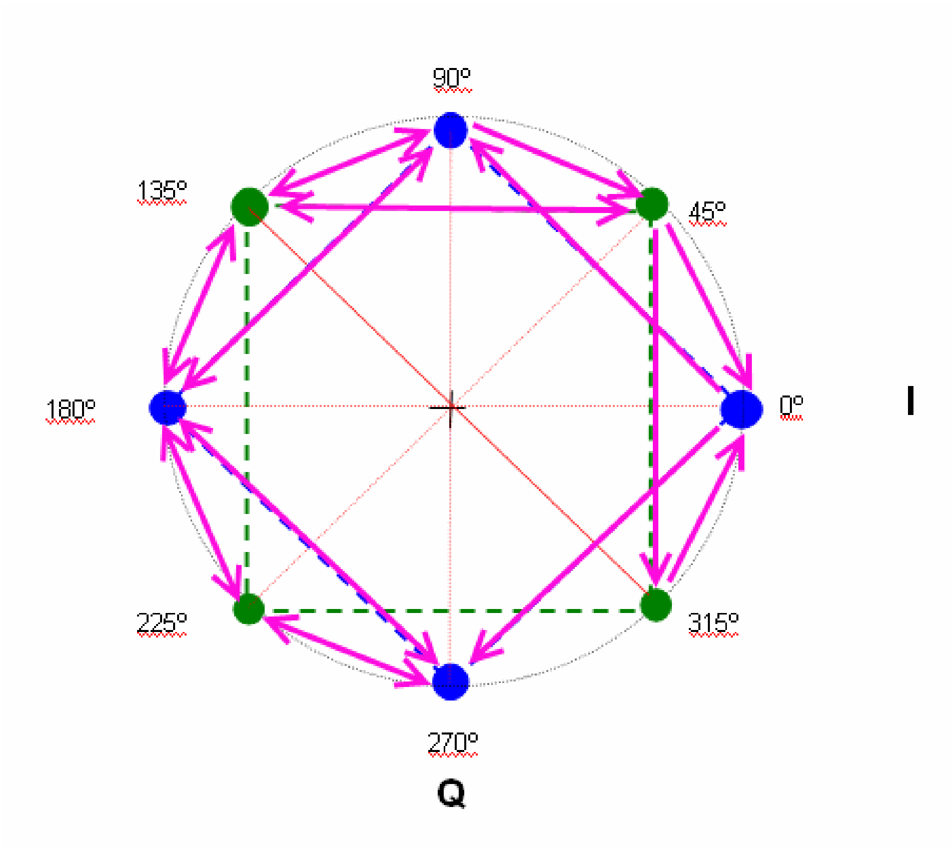
pi/4 DQPSK Transitions



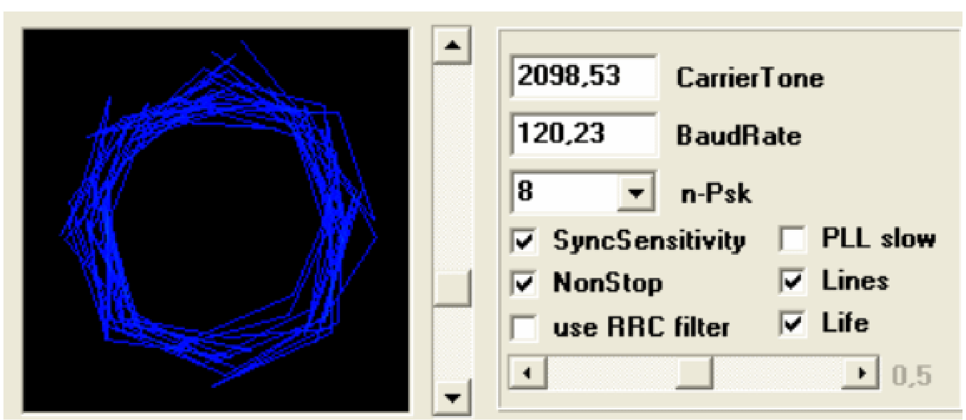
pi/4 DQPSK Trajectories



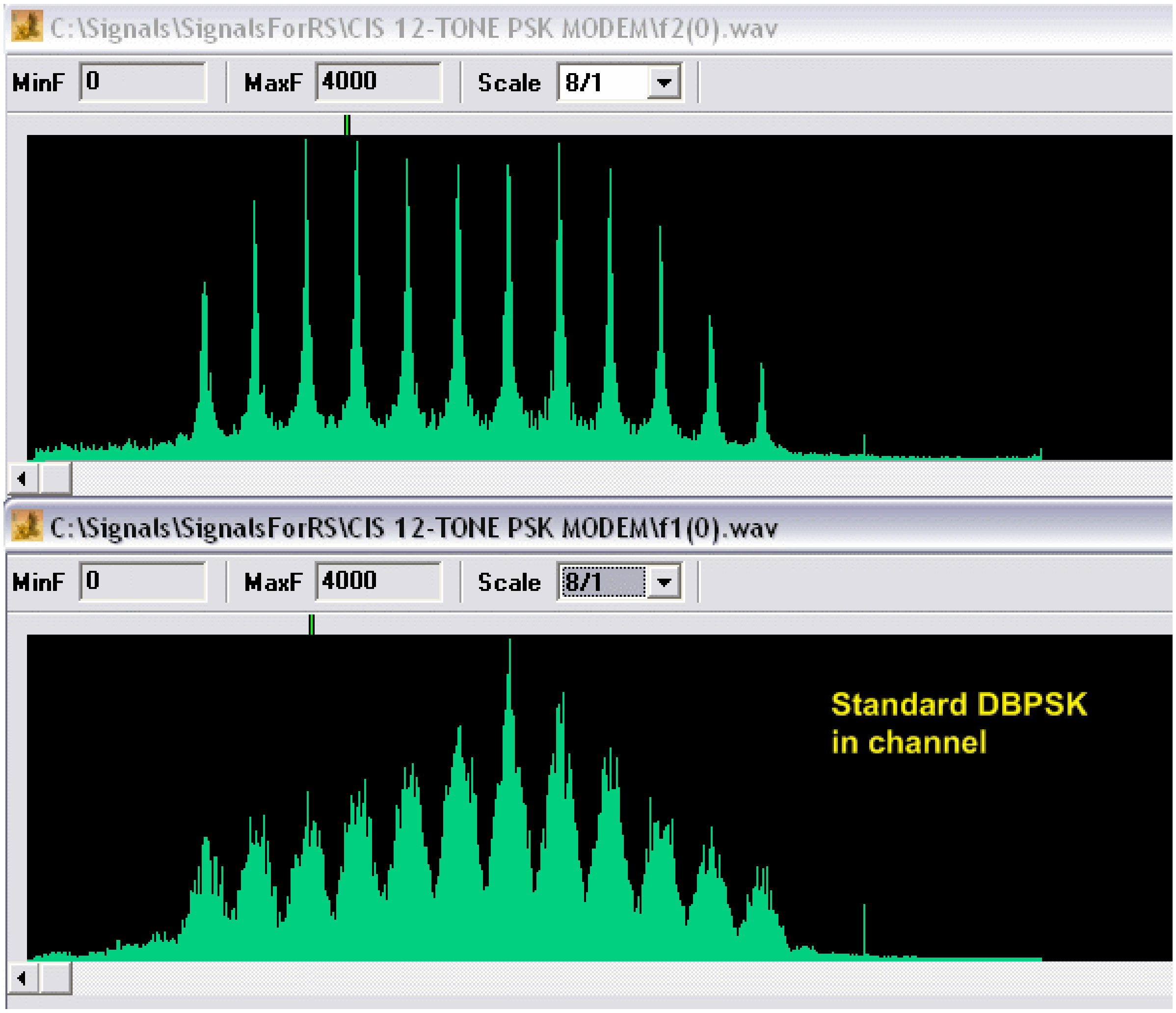
There also exists hybrid phase modulation methods, which reveal unusual spectra such as that of the CIS AT-3004 12-tone modem.



CIS mod-PSK AT-3004D modem Transitions



Contrasting with standard PSK, this modem's main energy is concentrated in very narrow bands.



All modes where the trajectories/transitions never pass through the origin, have a lower requirement to linear RF devices(e.g. output amplifier needs not to be highly-linear). The tradeoff for this tolerance is lower speed (SDPSK, pi/4 DQPSK), or difficult clock extraction (OQPSK), and other minor problems.

19.11.5.8 Few more observations.

PSK Demodulation

PSK is demodulated coherently by referencing against the phase of a local carrier. To ensure this is approximately 0° it is necessary to:

a. transmit a carrier phase reference adjacent to the data signal, or
b. derive the reference signal from the data signal itself.

Differential encoding (DBPSK/DQPSK).

Instead of using the bit patterns to **set** the phase of the carrier the alternative which can be used is to **change** it. The demodulator determines these changes in the phase received rather than the actual phase.

Since this system depends on the difference between successive phase it is termed Differential Phase Shift Keying (DPSK).

The plus side - Simpler implementation than PSK. There is no requirement for the demodulator to have a source of reference signal against which to determine the exact phase of the incoming signal.

The down side - Produces more erroneous demodulations.

Gray coding.

When the bits are mapped to adjacent/successive symbols this might result in one or more one bits changing.

Phase°	Bits	Bit changes
0	00	2
90	01	1
180	10	2
270	11	1

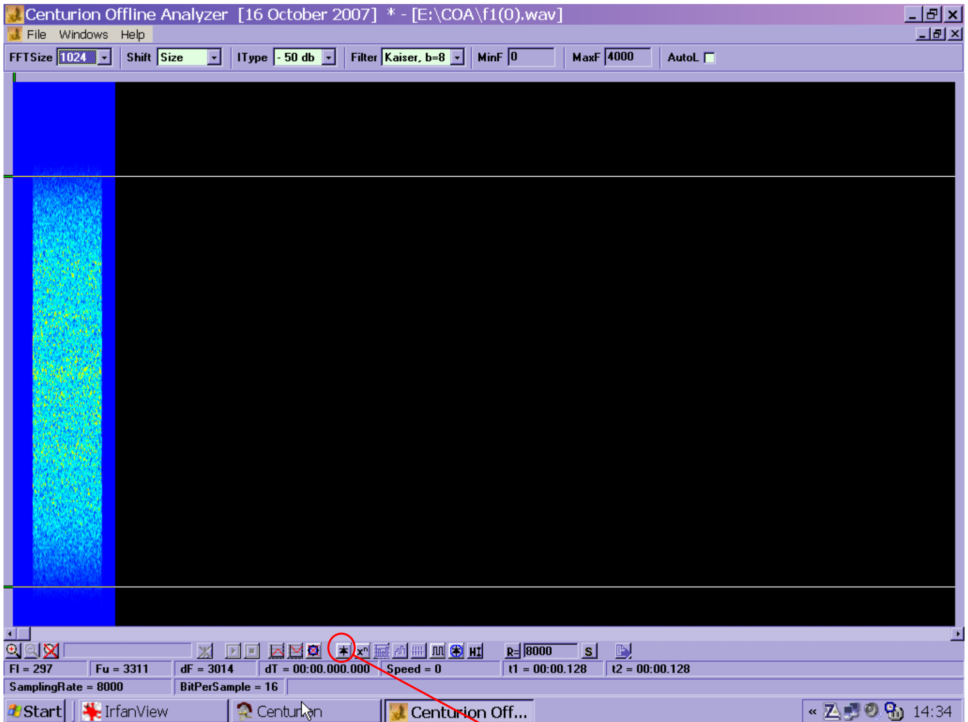
Phase°	Bits	Bit changes
0	000	3
45	001	1
90	010	2
135	011	1
180	100	3
225	101	1
270	110	2
315	111	1

For M-ary signalling the concept of Gray coding for optimising the bit error probability for a given symbol error probability is likely to be used. It is prudent to use an intelligent assignment of bit patterns to symbols in the constellation space to ensure that adjacent symbols only differ by one bit. Following is a typical example:

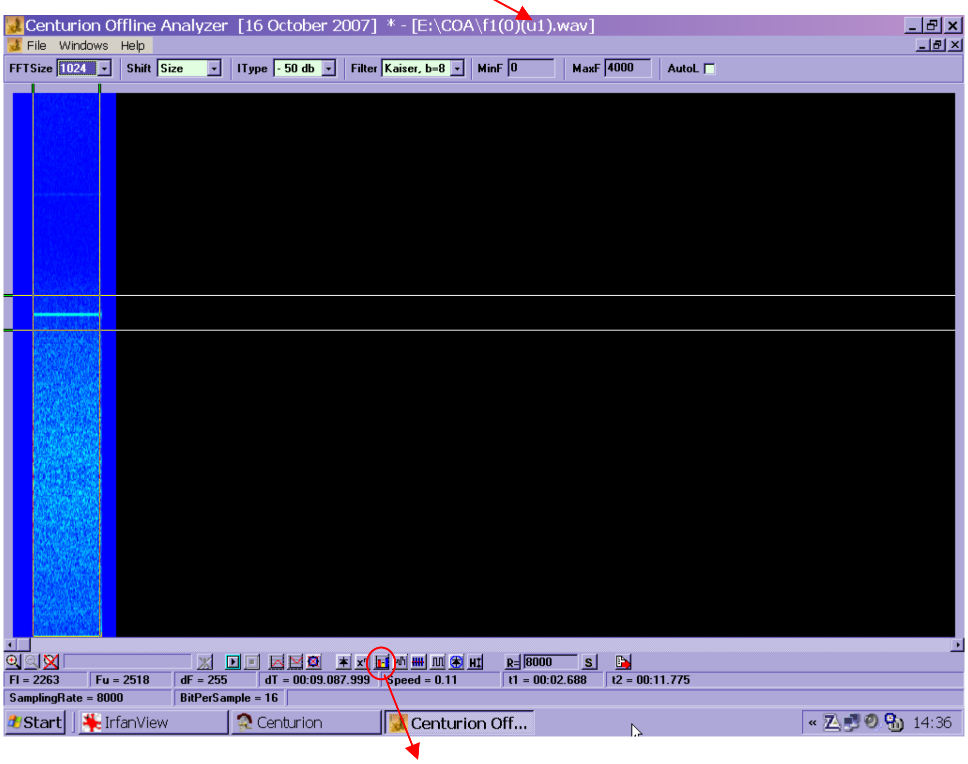
Phase°	Bits	Bit changes
0	000	1
45	001	1
90	011	1
135	010	1
180	110	1
225	111	1
270	101	1
315	100	1

19.11.6 Baudrate Correction Considerations.

This function corrects in order to indicate the exact baud rate. It first requires an initial correction of position of the carrier/subcarrier. First measure the each parameter as is.

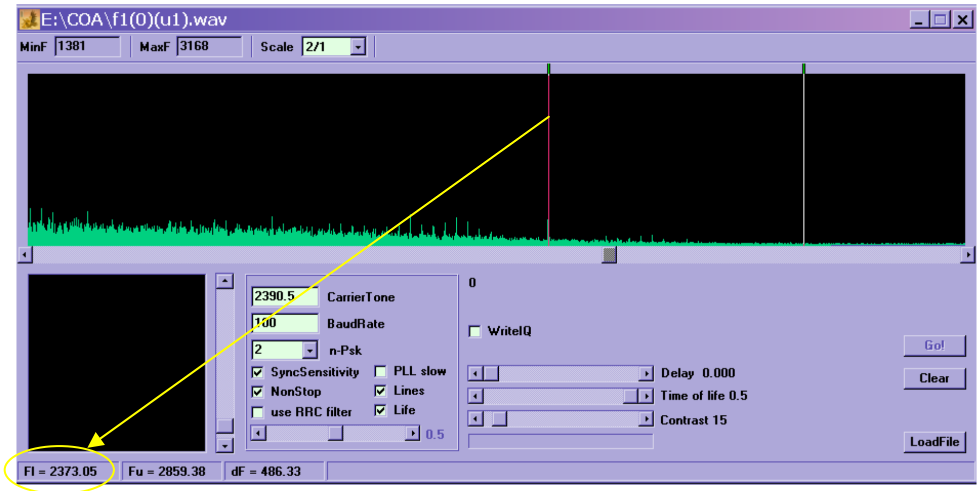


Taking the basic signal click the Quad Amp Detect button



and produce the baudrate line in the **u** window

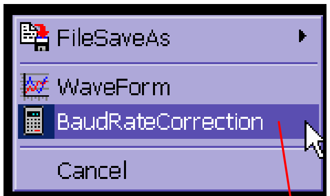
Delineate and call the High Resolution Viewer.



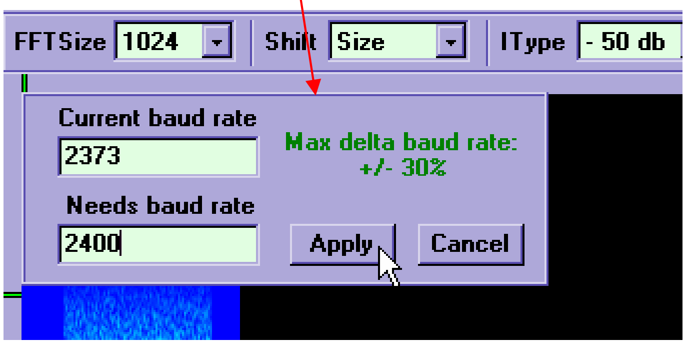
This indicates 2373

Carrying out the involutions function the **q** window indicates a subcarrier at 1780Hz and N-ary=8.

To apply a correction one returns to the source file window and right clicks it's window.



Baud rate correction is selected.

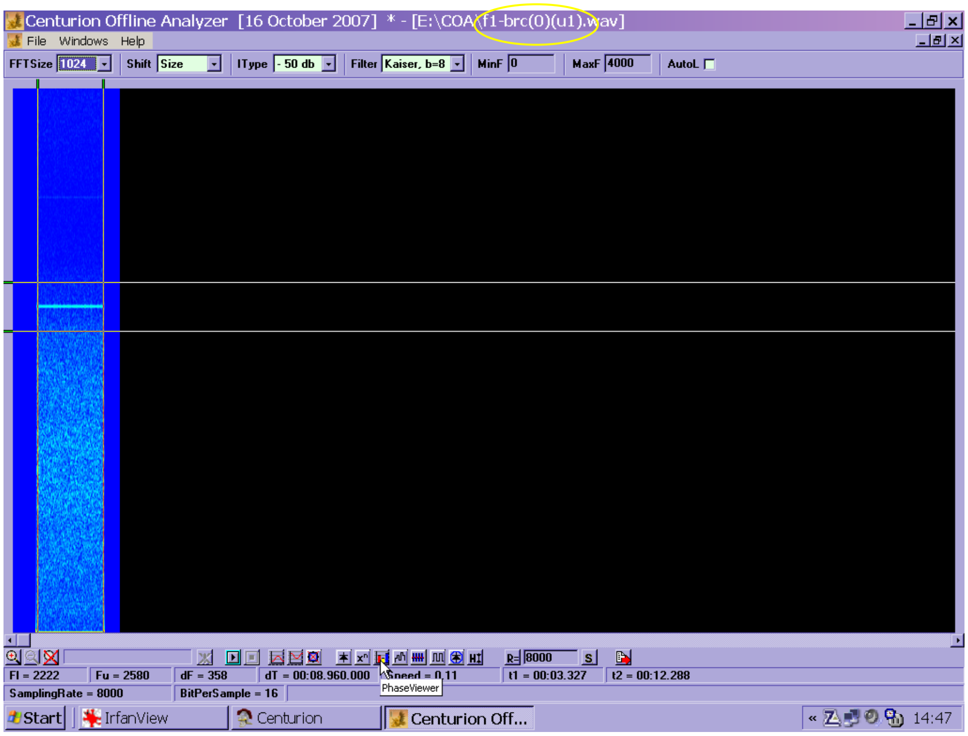


This causes a small entry box to appear on the top left corner.

The previously measured baudrate (2373) is entered, followed by the expected baudrate (2400).

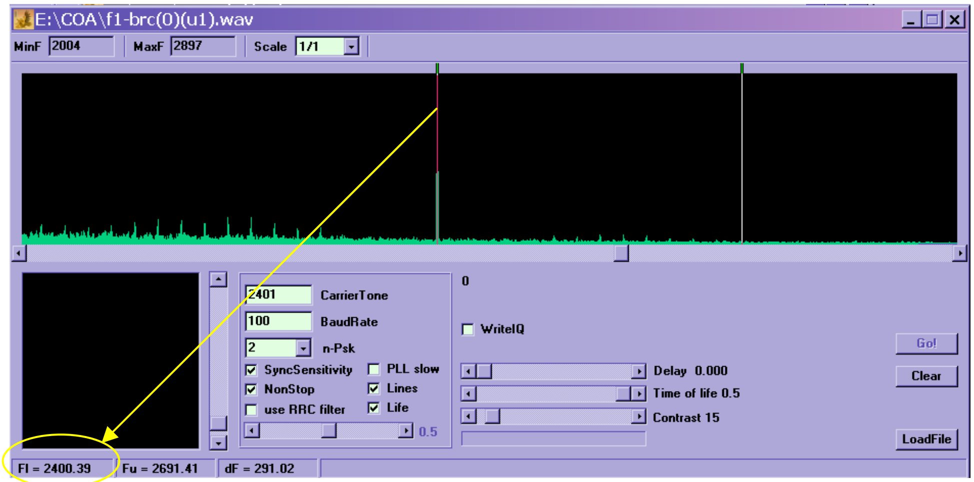
The Apply button is clicked.

This results in a corrected signal appearing in a **brc(0)** window. This is considered the new original file for a repeat of the analysis exercise. The first is to measure the baudrate.



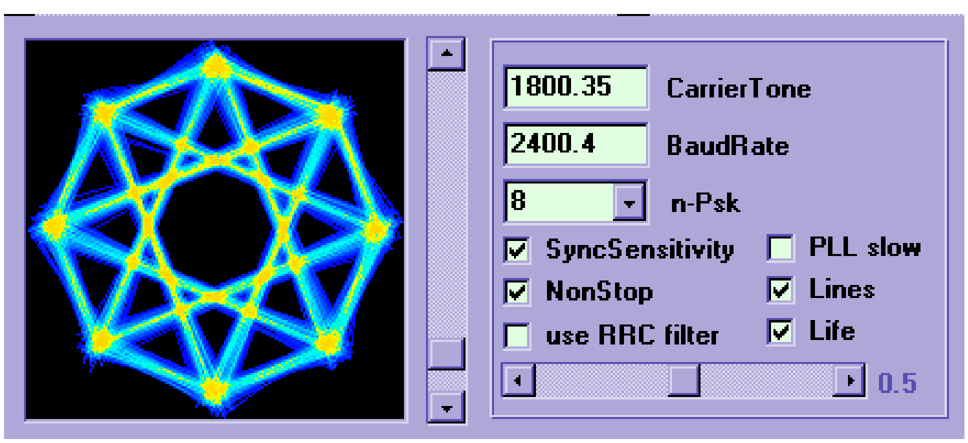
Note the **u** window with it's new **brc(0)** source.

Proceed to measure speed.



The speed is now 2400

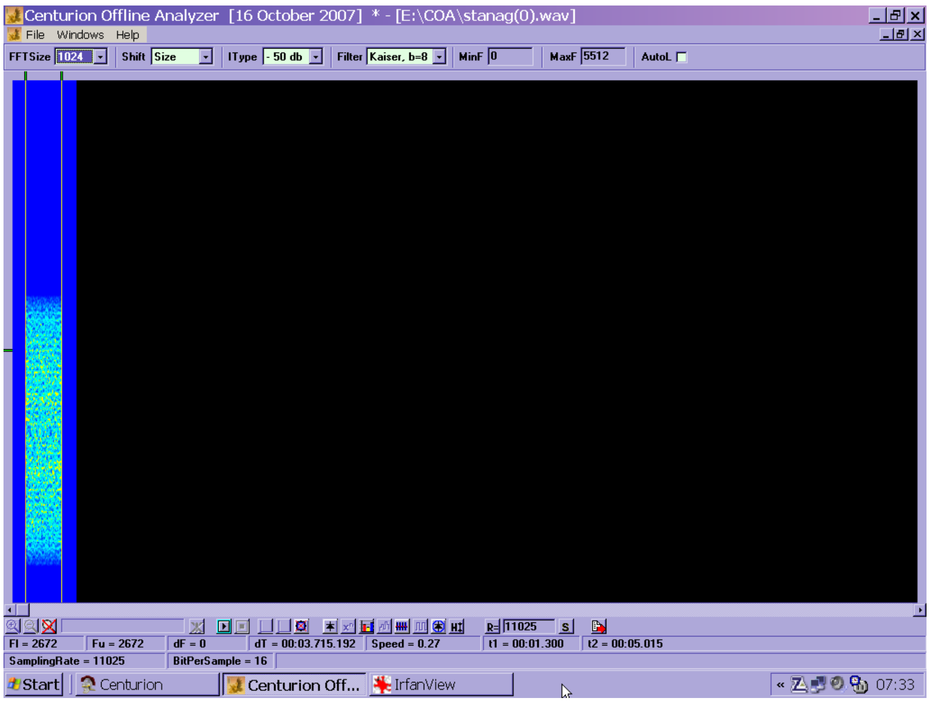
and the sub-carrier is 1800Hz

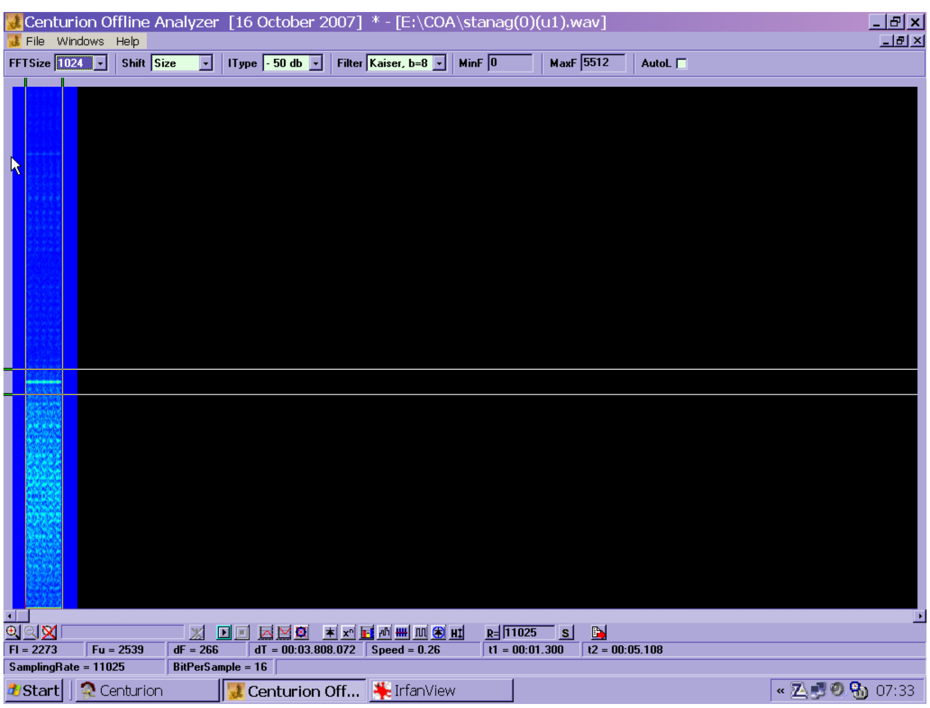


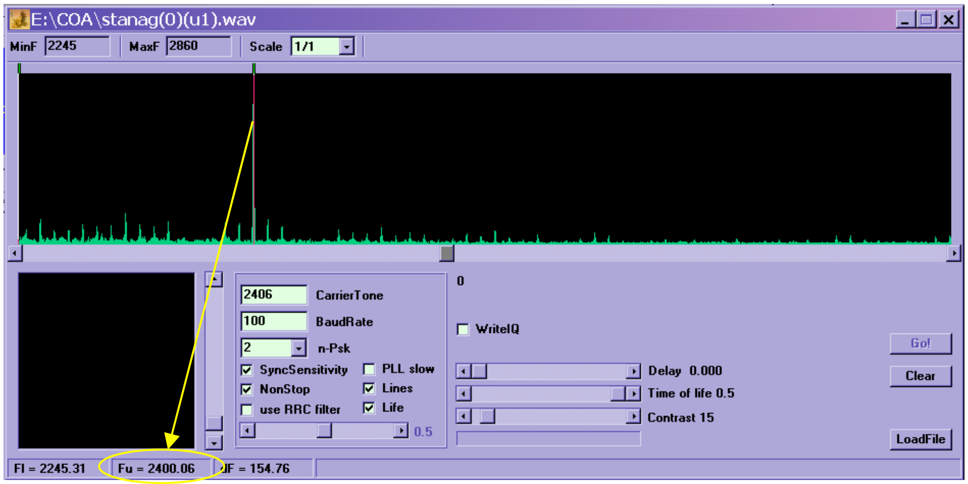
The constellation with corrected parameters.

The subcarrier offset is exactly 1800Hz because the receiver in this case was on VHF and general shift depends only on the soundcard sampling rate. General shift is synonymous with signal bandwidth - total spectrum of a signal without distortion between signal components.

For HF SSB general shift depends on sample rate but tuning accuracy is not critical for baud rate determination. However if one wants to correct baud rate use the general shift baud rate correction procedure as a first step. Then check and correct if required.



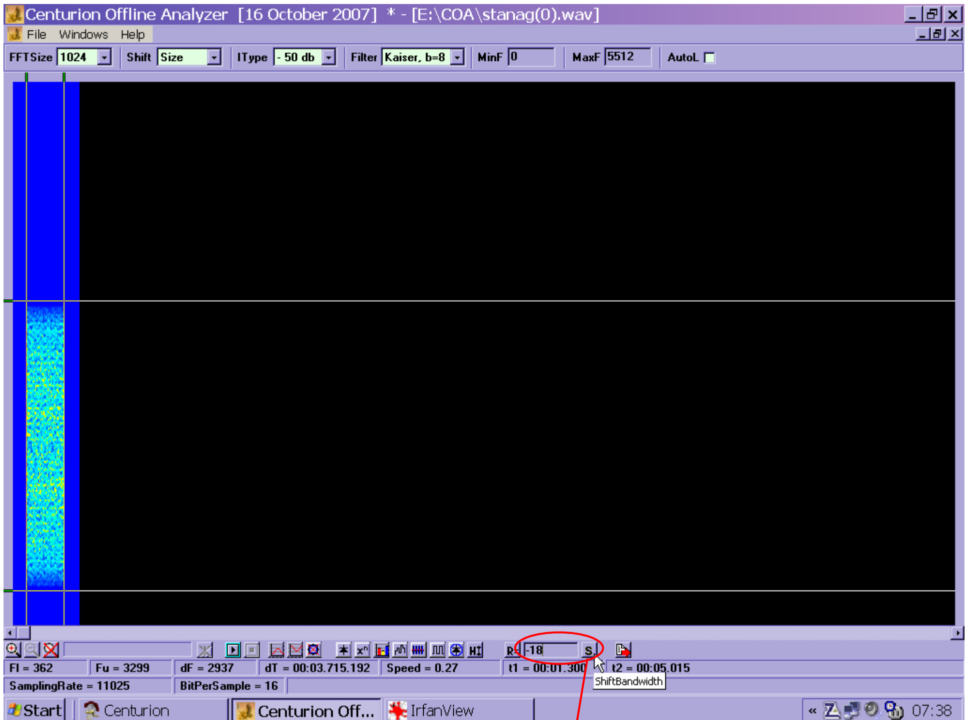




In the **q** window after involutions changes are complete the subcarrier is shown at ~ 1818Hz and N-ary is 8.

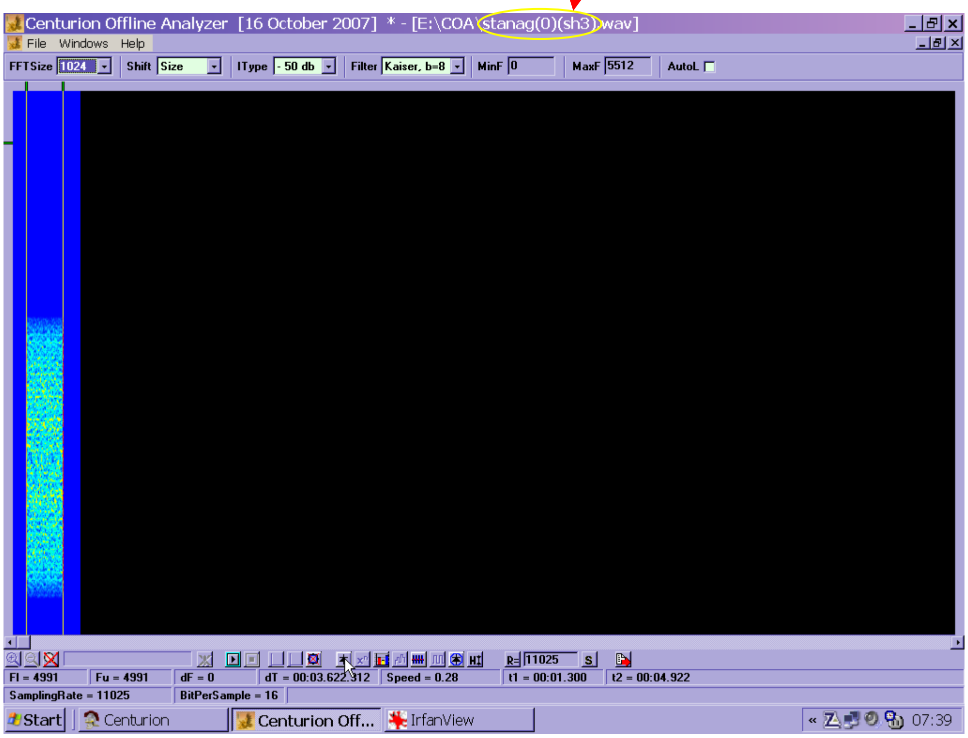
To correct this subcarrier it is necessary to use the required delta-shift ie
1818 --> 1800 Hz

or ~ -18

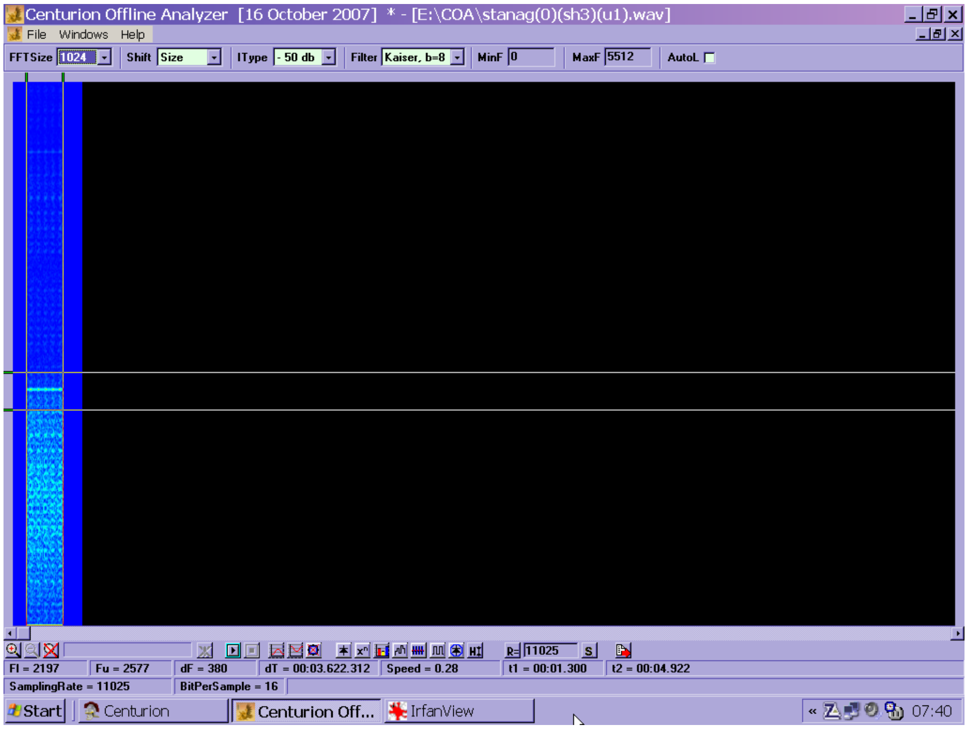


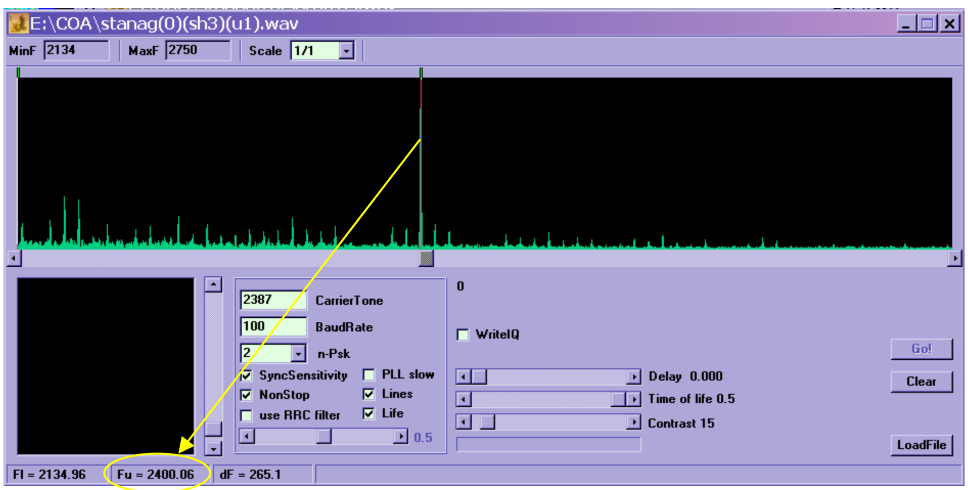
Return to the signal source window.

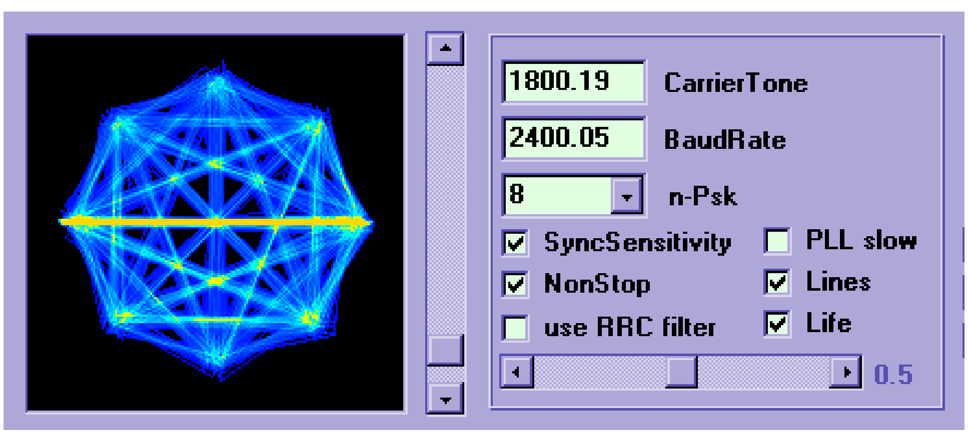
Enter the delta-shift value into the entry box and click the S button (ShiftBandwidth).



Calculations complete the new source signal for further analysis appears in a new **sh** window.







The constellation with corrected parameters.

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